2003

Soil landscape relationships on restored hillslopes on the Des Moines Lobe in central Iowa

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Soil landscape relationships on restored hillslopes on the Des Moines Lobe in central Iowa

by

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A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Soil Science (Soil Morphology and Genesis)

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Iowa State University

Ames, Iowa

2003

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DEDICATION

This dissertation is dedicated to my mother, Olga Moran, for her encouragement, love, and faith. This dissertation is also dedicated to Michelle and Alexander Patrick, for giving to me the best gifts of joy, happiness, and love.

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ACKNOWLEDGEMENTS

I would like to first thank Michelle and Alexander Patrick Moran for their support, patience, encouragements, faith, and love during my writing and research stages. I look forward to our life beyond student life. I also thank my parents, my sister, and my brother for their encouragement and support through my educational career. Special thanks are extended to Dr. Thomas Fenton for serving as my major professor. Thank you for giving me the opportunity to develop a research project and then endorse it. It was the best learning process a student could ever get. I also want to thank Drs. Lee Burras, David Laird, Thomas Loynachan, and Arnold van der Valk for serving on my committee and providing valuable suggestions and input to my dissertation. I would also like to thank the personnel in the Department of Natural Resources for providing field and literary assistance during my study. I would also like to thank Eric Brevik, Melissa Lauterbach, Chin Ming Cheng (Jeremy), and Kurt Arends for their laboratory and field assistance. Many thanks to all my friends for their support and encouragement.

ABSTRACT

Increased awareness of the economic and environmental values of prairie and wetland ecosystems has resulted in numerous areas of cultivated land being converted back to native ecosystems. Little information exists documenting the changes in soils and hydrology on these ecosystems. This dissertation includes studies of the hydrology, the sources of soil spatial variability, and the amount of carbon in restored prairie-wetland complexes in central Iowa.

Four general groups were developed to describe soil hydromorphology along the restored prairie-wetland hillslopes. Soil morphology was correlated with hydrology for all groups on the restored hillslopes. Mean and shallowest water table depths varied for all groups. Group I included Clarion and Nicollet soils on upland prairie summits with redoximorphic features restricted to Bg and Cg horizons. Group II soils included Delft and Webster soils on upland prairie-backslopes. Group III soils included Canisteo and Delft soils on wet prairie or sedge wetland-footslopes. In general, group II and III soils had thicker A horizons than group I soils with low chroma mottles or pore linings and Bg horizons with low chroma mottles, high chroma mottles or a combination of both. Group IV soils included dominantly Okoboji soils in closed pond depressions with sola having a mixture of low chroma mottles, high chroma mottles, and low/high chroma pore linings.

Soil depth explained most of the systematic variability in available K and P and total and organic C in upland prairies and wetland ecosystems. Sources of variability differed among prairie and wetland ecosystems for coarse silt, clay, bulk density, extractable cations, CEC, and pH. Highest soil microbial biomass C amounts and variability was in the upland prairie-backslopes. Slope position explained 52% of the total systematic variability in organic C. Soil depth explained for 74% of the total systematic variability in microbial biomass C. Our studies conclude i.) restored hillslopes are producing significant amounts of microbial biomass and organic C; ii.) longer term monitoring of water tables is required to better understand soil hydromorphic relationships; iii.) spatial relationships

and variability attributable to site, transect, vegetation, slope position, and depth should be considered when assessing restored hillslopes.

CHAPTER I: GENERAL INTRODUCTION

Wetlands comprise nearly 6% of total Earth land surface (Freeman et al., 1997). They provide many useful economical and environmental traits, such as sites for visitors engaged in hunting, fishing, and wildlife activities and for water quality improvement (National Research Council, 1995). Wetlands sequester approximately 15% of total world carbon (C) (Rabenhorst, 1995). Four significant global C pools are oceans, atmosphere, terrestrial ecosystems, and geological formations containing fossil and mineral C in the form of carbonates (Lal et al., 1995). The biggest C reservoir in terrestrial ecosystems is the soil. Organic and inorganic C pools are the major soil pools in terrestrial ecosystems. The organic pool is concentrated near the soil surface within the upper 100 cm. The inorganic pool commonly in the humid region is contained at greater soil depths and occurs dominantly as primary or secondary calcium carbonates. Wetland soils are critical C pools and are major sources of natural greenhouse gases, such as CO_2, methane (CH_4), and nitrous oxide (N_2O). Wetlands also maintain a wide range of redox reactions that recycle, transform and pool nutrients among the soil, water, and atmosphere differently than upland ecosystems.

The Des Moines Lobe is a physiographic region with high acreages of poorly and very poorly drained soils that are dominantly Mollisols, but also smaller acreages of Histosols or Entisols. These soils developed from surficial sediment transported from adjacent slopes higher on the landscapes and from organic materials deposited and filling former lakes or ponds. The Des Moines Lobe is part of the prairie pothole region with wet prairies dominating lower slopes. Wetlands have been exposed to significant changes in land use or management practices, altering its quasi-equilibrium status and yielding a newer one functional to its external (climatic) and internal (soil and plant) environmental properties. Such changes are either anthropic like conversion, restoration, and abandonment or natural, such as erosion and accumulation of sediments. These changes, in turn, impact and influence the biogeochemistry of the C cycle.

Soil C is a good indicator for understanding and modeling these disturbances and interactions. Soil C is a critical property that sustains diversity of plants and the availability of substrates for microbial processes. Organic matter also is considered an important indicator of soil quality. Soil quality is defined in simplest terms as the capacity of the soil to function (Karlen et al., 1997). Soil quality reflects the living and dynamic nature of the soil system and can be conceptualized as a "3-legged stool" whose function and balance is an integration of three components: sustained biological productivity, environmental quality, and plant and animal health. Studying soil organic matter dynamics and nutrient cycling is crucial in functional evaluations of wetlands. Spatial variability in soil properties, especially related to organic matter content and depth distribution, can reflect vegetative patterns and hydrologic influences.

Wetland distribution on a landscape depends on many factors. Parent material and hydrology are important in influencing water flow and storage. Soil geomorphology is crucial in assessing hydromorphology. Studies have shown that common field indicators of hydric soils are not readily observable in seasonally saturated and anaerobic soils along Mollisol landscapes (Thompson and Bell, 1998; Khan and Fenton, 1996). Thompson and Bell (1998) found saturated conditions within 25 cm of the soil surface for all soils along a Mollisol catena for at least a few days each year, mainly in the early spring or late fall seasons. Very poorly drained soils were saturated and anaerobic during the microbial activity season where the soil morphology reflected the presence of saturated and anaerobic conditions in the form of thick dark surface horizons. Steinwand and Fenton (1995) characterized the hydrology of a till landscape as recharge on topographic highs, lateral flow on sideslopes, and discharge in swales. On the Des Moines Lobe, soils on upper well drained landscape positions have oxidizing environments, and soils on lower landscapes have reducing conditions during most of the growing season (Khan and Fenton, 1994). These changes in redox potential and microbial activities along the landscape influences the C storage and variability.

Wetland Types and Traits

Common examples of defined wetland types in Iowa include natural, abandoned, converted, farmed, and prior conversion (U.S.D.A. and S.C.S., 1989). A natural wetland consists of those areas with predominantly hydric soils capable of supporting water-loving plants. Abandoned wetlands include those areas previously altered and farmed but recently abandoned as cropland with no attempt for maintenance as cropland for at least five consecutive years and now supporting water-loving plants. Converted wetlands include wetlands with hydric soils drained or altered after 12/23/85 to allow for agricultural use. Farmed wetlands are wetlands partially drained or altered to agriculture use prior to 12/23/85. Prior conversion refers to wetlands converted to cropland use before 12/23/85 where the land was completely drained or altered to enable crop production and now does not meet wetland criteria for hydric soils or hydrophytic vegetation.

Wetland hydrology, hydrophytic vegetation, and hydric soils are parameters in the characterization of wetlands (National Research Council, 1995; Wangpakapattanawong, 1996). Hydrophytic vegetation consists of macrophytic plants suitable for growth in substrates periodically deficient in O_2 due to saturation. Hydric soils consist of soils formed under periods of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper solum. Wetland hydrology requires the water table to be within 30 cm of the soil surface for a continuous period >5% of the growing season in one out of every 2 years. Saturation is the dominant biogeochemical process in wetlands. Lowering of the water table reduces saturated conditions and modifies the soil system. This modification may result in lowering the release of methane and dissolved organic C and increase the mobilization of inorganic nutrients and of C as CO_2 (Freeman et al., 1997).

Microbial processes are critical in the functional evaluation of nutrient cycling, soil quality, water quality maintenance, and restoration or construction designs of wetlands. Microbial processes enhance the degradation of organic materials and the cycling of nutrients in these ecosystems

(Freeman et al., 1997). Microbial populations influence the immobilization and degradation of nutrients, organic compounds, and other pollutants. Variation in microbial processes can exist within and between wetlands due to factors such as organic matter type and dynamics, hydrology, plant type and dynamics, and natural or anthropogenic disturbance (Groffman et al., 1996). Variations in ecological properties and the fact that wetlands are an integrated product of many environmental conditions suggest distinct patterns of microbial activity occur in these systems. Enzyme activity in wetlands is considered low and may affect wetland functions in numerous ways. Examples include accumulation of partially decomposed plant materials (C sequestration), sequestration and retention of inorganic nutrients within the poorly degraded plant materials, and subsequent availability of energy sources from the recalcitrant organic matrix to regulate microbial production of trace gases.

Nature of the parent material also influences the wetland status, spatial variation, and microbial processes. Groffman and Tiedje (1989) reported wetlands developed on nutrient-poor parent materials supported vegetation with low nutrient status. This vegetation consequently produced litter low in C and N and supported low levels of microbial activity. Groffman and Hanson (1997) reported very poorly drained soils and soils developed on nutrient-rich parent materials had higher denitrification rates than well-drained soils and soils developed on nutrient-poor parent materials. Soil gradients exist in wetlands based on hydrologic influences (Reese and Moorehead, 1996). Reese and Moorehead (1996) studied spatial characteristics along an elevation gradient in a Carolina Bay wetland and reported that sampling protocols from wetland soils may require an evaluation of the elevation, hydrology, and vegetative patterns for determining spatial patterns of nutrient cycling.

Carbon Cycles and Processes

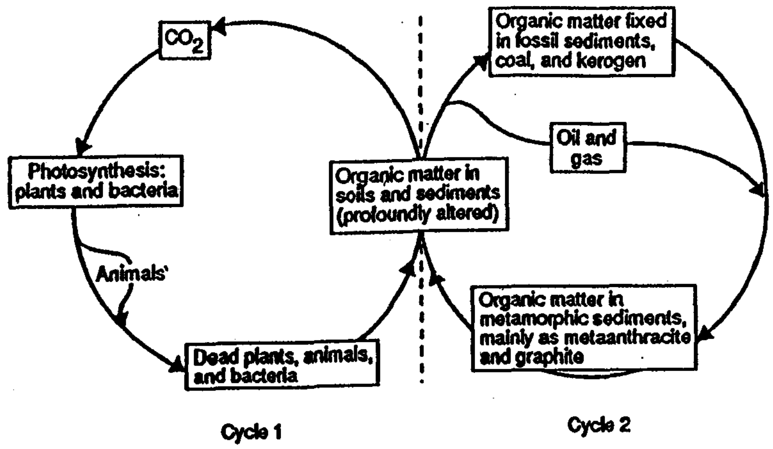

Figure 1. Major cycles of organic C (Bogner and Spokas, 1995).

Biogeochemistry of the C cycle in wetlands requires understanding the large annual transfer of atmospheric CO_2 to plants during photosynthesis and the return of atmospheric CO_2 during microbial and vegetative decomposition. The largest exchange of C is between the atmosphere and the terrestrial plants. Gross primary production is dominantly the C fixed by terrestrial plants. A review from Stern (1988) will describe the major processes of C cycling. Organic C cycle can be divided into two cycles (Figure 1). Cycle 1 involves the short-term cycle where C is recycled to atmospheric CO_2. CO_2 is taken up by plants and microorganisms and subsequently decomposed and sequestered into organic matter constituents in soils and sediments. Cycle 2 involves the long-term cycle of incorporation of organic C in sedimentary storage chemically and physically transformed by increased heat and pressure through time (Bogner and Spokas, 1995). Cycle 1 represents the major C cycling for landscapes in the Des Moines Lobe. Therefore, understanding C dynamics of landscapes on the Des Moines Lobe requires a brief summary of the photosynthesis-respiration cycle.

Photosynthesis is an energy storing process with the key components in the process being CO_2, water, light, sugar and O_2 (Figure 2). The general reaction for photosynthesis is (Stern, 1988): $6CO_2 + 6H_2O + light\ energy \rightarrow C_6H_{12}O_6 + 6O_2$. Light energy is stored in simple sugar molecules that are produced by CO_2 in the atmosphere and water absorbed by plants. O_2 diffused into the atmosphere. The site of photosynthesis is the chloroplast in mesophyll cells. CO_2 diffuses through the stomata and moves into solution in the thin water film outside walls of cells. CO_2 then passes through the cell walls into the cytoplasm and reaching the chloroplasts. Water absorbed by plants is dominantly transpired or incorporated into protoplasm and other cellular constituents. The remaining absorbed water is used in photosynthesis and provides a source of energy released during photosynthesis. Water content strongly influences CO_2 uptake. A low water supply induces closure of the stomata and the reduction of CO_2 uptake. Dominantly visible light in the blue-violet and red-orange wavelengths is used during photosynthesis. Light intensity also influences photosynthesis by increasing transpiration, which enhances the closure of the stomata and reducing the CO_2 uptake.

Light and dark reactions control the process of photosynthesis (Stern, 1988). Light reactions involve light striking chlorophyll molecules present in the chloroplasts and the conversion of light energy to chemical energy. Water molecules are split apart, producing hydrogen ions and electrons and releasing O_2 gas (Figure 2). Adenosine triphosphate (ATP) is formed and the hydrogen ions generated are involved in $NADPH_2$ formation. Dark reactions are those that occur outside the grana in the stroma of chloroplasts. The Calvin Cycle is the most common of the dark reactions and involves the combination of a 5-C sugar, known as ribulose biphosphate (RuBP) and CO_2 in the atmosphere into a 6-C sugar, such as glucose. Energy and other constituents are provided by ATP molecules and $NADPH_2$ generated during the light reactions. Most of the resulting 6-C sugars are recycled or stored as starch or other polysaccharides.

Soil organisms can utilize the energy-containing organic compounds through various respiration processes, which release small amounts of usable energy and storing it in ATP molecules. This allows for efficient use of the available energy. Respiration is initiated in the cytoplasm and completed in the mitochondria (Stern, 1988). Three kinds of respiration are recognized: aerobic respiration, anaerobic respiration, and fermentation. Aerobic respiration is the most common type

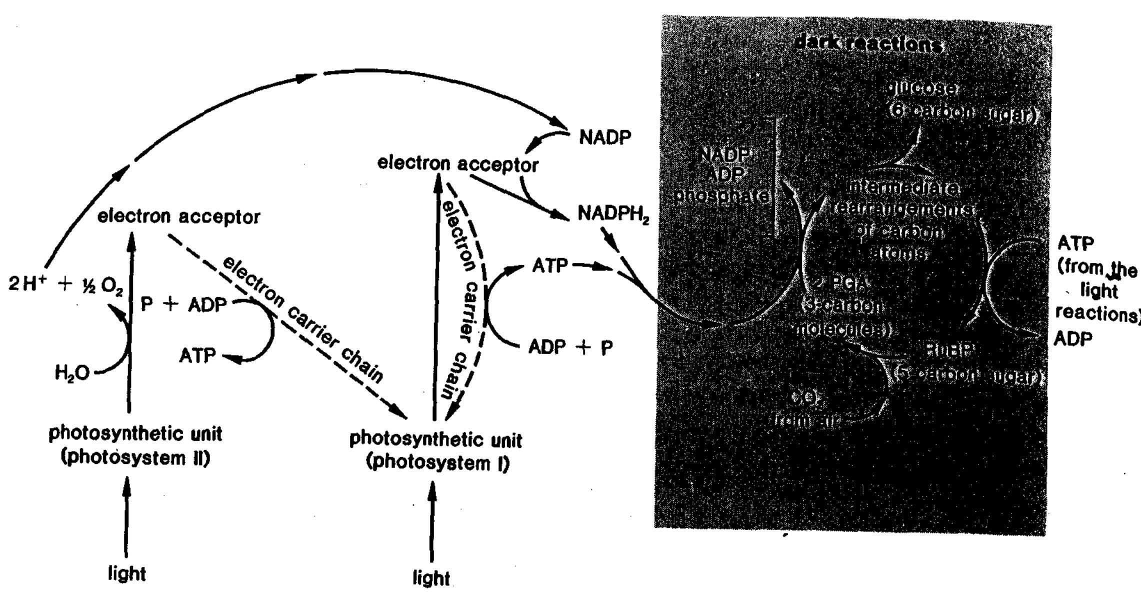

Figure 2. Summary of photosynthesis (Stern, 1988).

and involves energy released from simple sugar molecules broken down through a series of enzymatically-controlled steps completed with O_2 gas. CO_2 and water are released as by products. The general reaction is the following: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + energy$. Anaerobic respiration involves the degradation of the organic constituents occurring in the absence of O_2. Fermentation differs from the above by lacking an electron transport chain.

Three major cycles important in aerobic respiration are glycolysis, Krebs cycle, and the electron transport chain (Figure 3). Glycolysis is the first phase of respiration. It requires no oxygen gas and occurs in the cytoplasm of cells. The reaction involves three major enzymatically controlled steps. The first step comprises the conversion of glucose to fructose molecule carrying two phosphates. The second step comprises the splitting of the fructose molecule into two 3-C fragments. The third major step is the removal of some hydrogen, energy, and water from the 3-C fragments and the production of pyruvic acid. Glycolysis is initiated by the energy supplied from two ATP molecules. A net gain of 2 ATP molecules is achieved from the energy released during this process. The hydrogen ions and electrons released are subsequently incorporated into nicotineamide adenine dinucleotide (NAD) and flavin adenine dinucleotide (FAD), and used for different forms of respiration. The Krebs cycle occurs in the matrix between cellular cristae membranes of the mitochondria. The cycle also involves a series of enzymatic-catalyzed reactions. A general form of the cycle is the following (Stern, 1988):

$$\text{Oxaloacetic acid} + \text{acetyl CoA} + \text{ADP} + \text{P} + 3\ \text{NAD}^+ + \text{FAD}^+ \rightarrow \text{oxaloacetic acid} + \text{CoA} + \text{ATP} + 3\text{NADH}_2 + \text{FADH}_2 + 2\text{CO}_2$$

CO_2 is released from pyruvic acid produced during glycolysis with remaining restructured to a 2-C acetyl group. The acetyl group subsequently combines with the acceptor molecule, coenzyme A, to produce the product acetyl-CoA. This product then enters the Krebs cycle and undergoes a series of enzymatic-catalyzed chemical reactions. With progression of the cycle, partial amounts of energy and hydrogen are successively removed from a series of organic acids until conversion of the

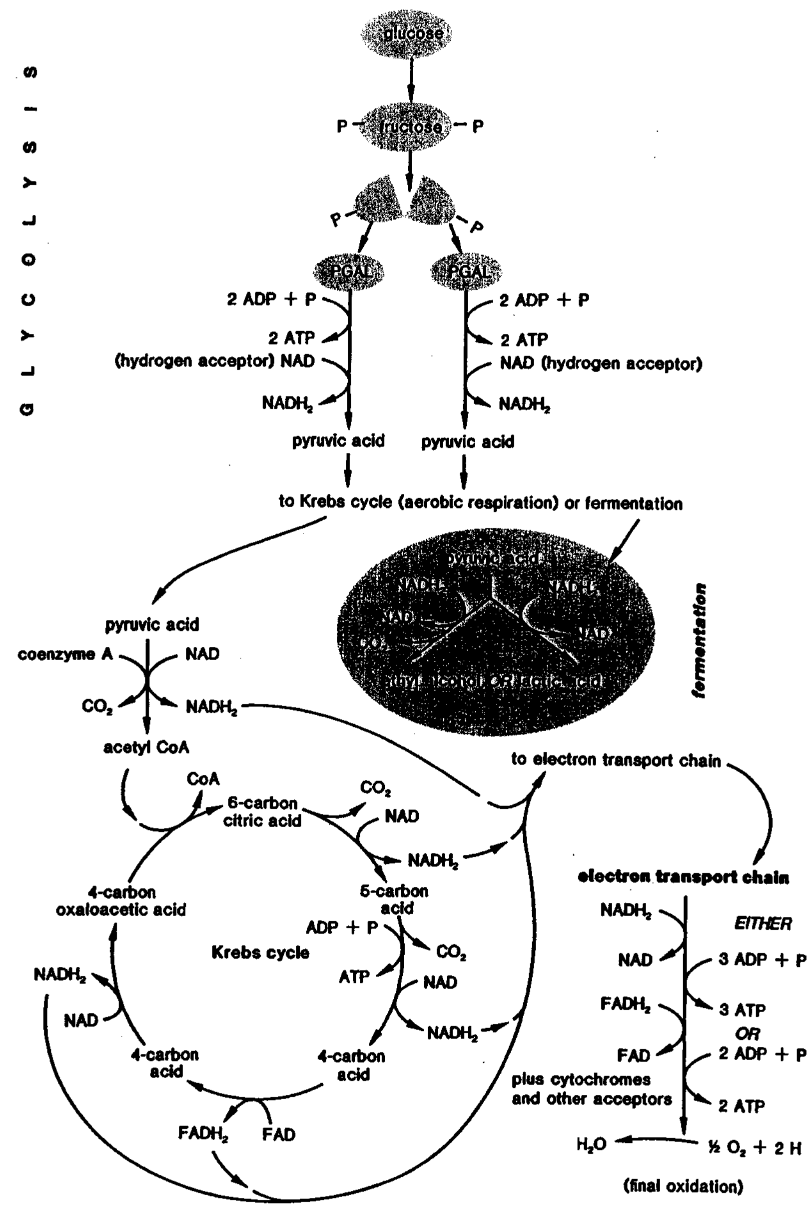

Figure 3. Diagram of respiration (Stern, 1988).

remaining energy to compounds as $NADH_2$, ATP, and $FADH_2$ and the release of CO_2 as a by-product. The electron transport chain is a cycle that comprises a chain of special acceptor molecules that release energy, form water molecules, combine electrons with atmospheric O_2, and produce ATP from ADP with subsequent release of energy. The energy sequestered in the glucose molecules has been released with substantial amounts subsequently stored in ATP molecules. This stored energy can be utilized in the synthesis of other molecules, cellular growth, active transport, or other metabolic processes. A net gain of 36 ATP molecules is produced during aerobic respiration from 1 glucose molecule with 6 molecules of oxygen used and 6 molecules of water and CO_2 produced.

During anaerobic respiration, hydrogen released during glycolysis is transferred from hydrogen electron acceptors (ie, $NADH_2$) back to pyruvic acid and creating commonly ethyl alcohol, lactic acid or other organic compounds. Little energy is released with the majority of the energy sequestered in the organic alcohols or acids produced or dissipated as heat. A net gain of 2 ATP molecules is generated during a cycle of anaerobic respiration.

Biogeochemistry of Terrestrial Ecosystems

Soils on upper well-drained landscape positions have oxidizing environments, and soils on lower landscapes have reducing conditions during most of the growing season (Khan and Fenton, 1994). Therefore, upper landscape positions are associated with terrestrial environments and lower landscape positions relate more with wetland environments. Photosynthesis is a biogeochemical process converting oxidized C, as CO_2, in the atmosphere to reduced organic forms incorporated into plant constituents and providing essential energy for all prevailing life forms in the ecosystem (Schleslinger, 1997). The oxygen supply influences the pathway of chemical transformations in the soil. The fraction of pore space filled by water controls the oxygen supply (Scholes et al., 1999). CO_2 and NO are the main gases emitted in aerobic systems with methane consumed through oxidation at low rates. Anaerobic microsites can occur releasing C as methane.

The two main C pools are the plant biomass and the soil (Scholes et al., 1999). The upper limit of C accumulation of plant biomass is controlled mainly by climatic factors. These factors determine, in turn, the types of plants coexisting in a given environment and the prevailing disturbance controls. The soil C pool is influenced by factors such as the depth of soil profile, the water regime, temperature, and the type and quantity of clays present. Commonly more clay is associated with greater C sequestration. Greater C sequestration is also associated with high-activity clays such as smectites (Scholes et al., 1999). Long term storage requires that C be converted to a form that is physically occluded or chemically resistant to decomposition. Humus is regarded as non-cellular organic matter due to the enhanced microbial activity and decomposition of plant litter and soil microbes. Most of the production of CO_2 is at the surface where litter decomposition is rapid and large concentrations of root biomass occur. The flux of CO_2 at deeper soil depths is likely associated with the decomposition of humic substances. Most of the net primary production is returned to the soil and undergoes efficient decomposition. Efficient decomposition evolves substantial evolution of CO_2 and C incorporation to microbial constituents, contributing low amounts of C to long-term storage of soil organic C. The soil organic pools, thus, comprise a dynamic pool near the surface and a recalcitrant pool of humic substances dispersed throughout the soil profile. The dynamic pool consists of rapid turnover of fresh plant detritus and little long-term accumulation of organic C.

Biogeochemistry in Wetland Ecosystems

Wetland sediments or soils are deficient in O_2, which diffuses over 10000 times slower in water than air (Schlesinger, 1997). Wetland environments vary changing from one where aerobic metabolism of organic matter is possible to one where anaerobic or fermentative metabolisms are required. The redox potential of the sediment or soil system controls the nutrient cycling in wetlands. Microbial transformations of nutrients in the O_2 deficient environment also influence C cycling in wetlands. Anaerobic metabolism results in incomplete or inefficient decomposition of organic substrates storing significant amounts of organic C. The biogeochemical reactions in these systems are related to the adjacent reactions in terrestrial environments through the movement of surface runoff and groundwater. The redox potential measures the tendency of an environment to receive or supply electrons. Anaerobic environments are considered low redox potential systems due to the low amount of O_2 as major electron acceptors. The redox potential, in turn, determines the mode and extent of microbial activity possible.

Organic matter reduces the redox potential of wetland environments due to its corresponding large reducing power (National Research Council, 1995; Schlesinger, 1997). Incomplete decomposition leaves undecomposed organic matter in the soil or sediment with highly decomposed humic substances imparting acidity to the soil solution. The lowering of redox potentials occurs as aerobic respiration of C carbon depletes the soil of oxygen. Upon complete depletion of oxygen from the soil environment, nitrate (NO_3^-) is utilized as an alternative electron acceptor during oxidation of organic matter (+747 mV at pH 7.0), in a process known as denitrification. Upon utilization of NO_3^- as alternative electron acceptor, emerges the zone of manganese (Mn^{+4}) reduction (+526mV) followed by the zone of iron (Fe^{+3}) reduction (-47mV). An overlap exists among the zone of denitrification and the zone of Mn reduction as a result of persistent facultative anaerobes tolerant to aerobic situations. No overlap exists between the zones of Mn and Fe reduction due in part to soil microorganisms exhibiting enzymatic preferences for Mn^{+4}.

Most of the reactions in wetland environments are performed by soil obligate anaerobes below the zone of Mn reduction. Also numerous microorganisms couple the reduction of Mn and Fe directly to the oxidation of simple organic compounds. Some of the species use fermentation to obtain their metabolic energy while others oxidize hydrogen by using Mn^{+4} and Fe^{+3} as electron acceptors. The following reactions illustrate this process (Schlesinger, 1997):

$$C_6H_{12}0_6 \rightarrow CH_3COOH + CH_3CH_2COOH + CO_2 + H_2$$

$$2Fe^{+3} + H_2 \rightarrow 2Fe^{+2} + 2H^+$$

The zones of sulfate reduction (-221mV) and methanogenesis (-224mV) emerge after the zone of Fe reduction. Methanogenesis in wetland environments can occur by two common pathways: acetate splitting and CO_2 reduction. The common reaction for acetate splitting is:

$$CH_3COOH \rightarrow CO_2 + CH_4$$

The common reaction for CO_2 reduction is:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Fermenting bacteria generate acetate-type compounds from cellulose decomposition. H_2 is generated as a by-product of fermentation. The CO_2 is found as HCO_3^-, which serves as an alternative electron acceptor. Little or no overlap exists between the zones of sulfate reduction and methanogenesis in wetland soils or sediments. Important factors influencing the flux of methane include the water table depth, the supply of labile organic matter, and the net wetland ecosystem productivity.

Biomethylation is another important microbial process in wetland environments (Schlesinger, 1997). This process is involved with the conversion of a heavy metal ion (M^{+2}) to a methylmetal form (CH_3M^+) toxic or hazardous in biota. However, this reaction is common in wetlands that are very anoxic and with low pH.

Wetlands can serve as a sink or source of nutrients. Their environments are characterized by low redox potentials. Nutrients received from adjacent landscapes are commonly transformed during their passage through the wetland ecosystem (Figure 4, 5). Emergent plants dominate the ecology in wetlands. Wetlands serve a biogeochemical role as a source, sink, and transformer, whereas their adjacent terrestrial systems are commonly biogeochemical sources of nutrients (Schlesinger, 1997, National Research Council, 1995).

Net vegetative productivity is low to medium in terrestrial ecosystems but is generally high in wetlands. Terrestrial ecosystems have dry hydrologic regimes, whereas wetlands have intermittent to permanent wetness. This wetness can impede decomposition accounting for large accumulation of organic material. The position on the landscape also influences the biogeochemical role. Commonly, wetlands in low topographic positions function as effective nutrient sinks. Therefore, O_2 deficiency in these environment results in incomplete metabolism of organic C, the accumulation of intermediate products, the evolution of substantial quantities of CH_4, partial quantities of H_2 in addition to CO_2,

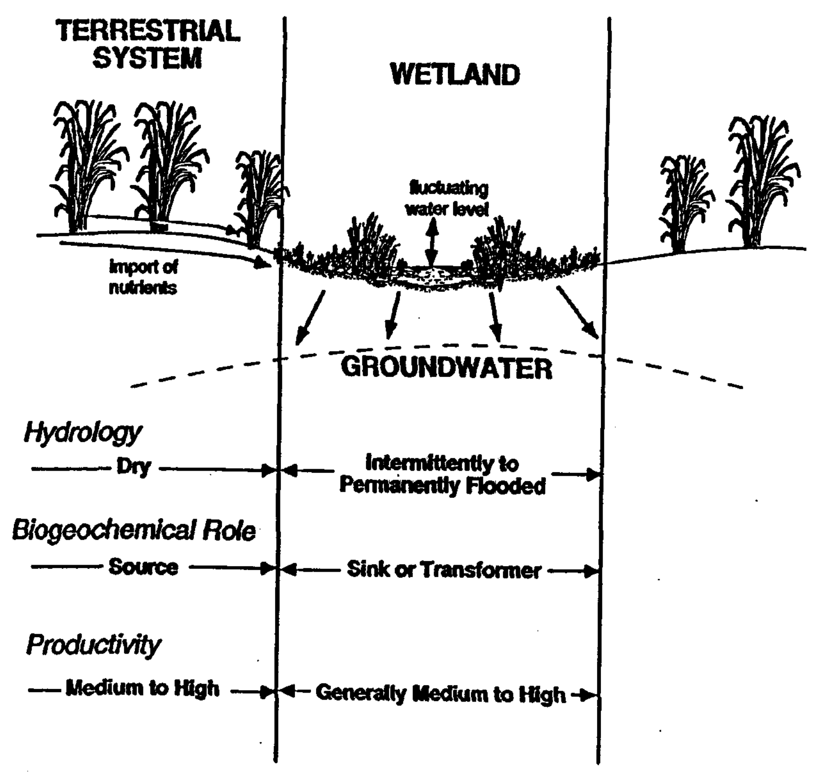

Figure 4. Biogeochemistry between terrestrial and wetland ecosystems (Schlesinger, 1997).

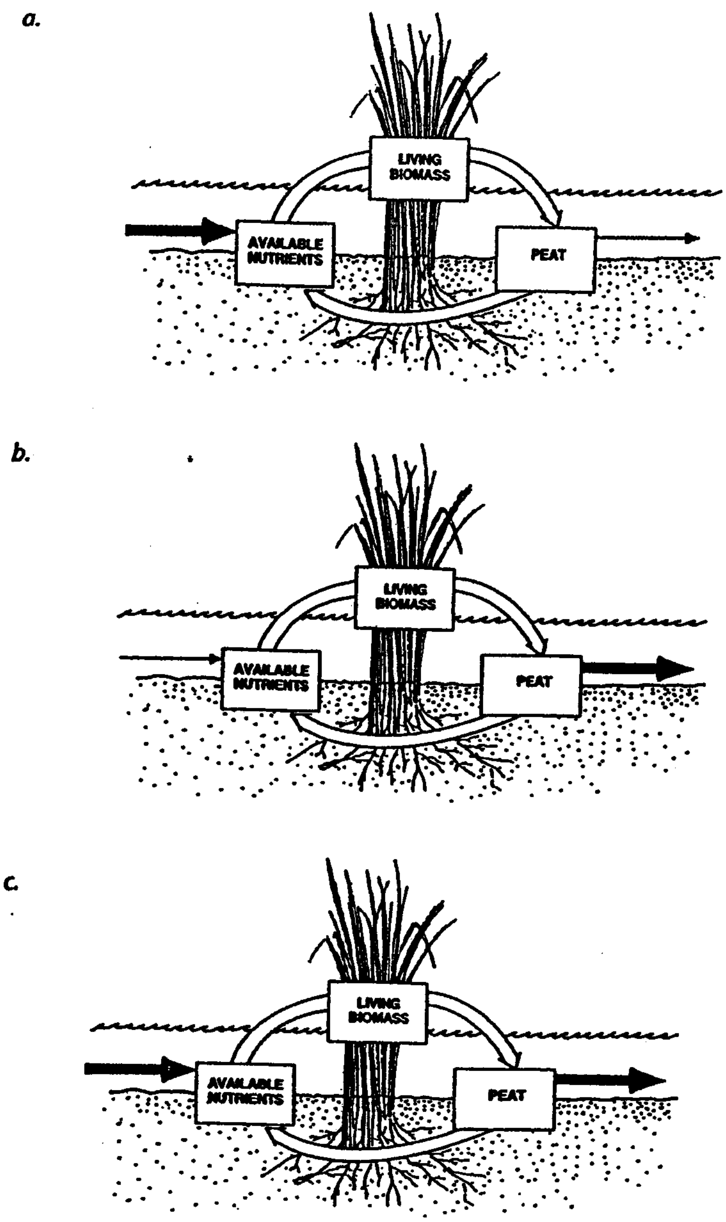

Figure 5. Biogeochemical roles of wetlands a.) sink; b.) source; c.) steady state (Schlesinger, 1997).

and low energy yields. Complete anaerobiosis generates slow decomposition but the rate in water-saturated soils is intermediate between total aerobiosis and anaerobiosis. Fermentation accumulates numerous organic constituents such as acids, alcohols, and carbonyl compounds. Organic acids include typically acetic, formic, and butyric acids. The acids, alcohols, and carbonyl compounds serve as energy sources for the fermentative organisms. The end products of anaerobic C metabolism are the formation of organic acids, alcohols, methane, and CO_2.

Long-term Carbon Pools

Two forms of C present in soils are organic and inorganic carbonates (Lal et al., 1995). Inorganic C can occur in parent materials such as limestone, calcareous sediment, loess and till and can occur in soils as secondary forms of carbonate accumulations in soils. Different forms of organic C occur in soils (Eswaran et al., 1995). The labile pool is readily oxidizable and controlled by residue inputs and climate. The slowly oxidizable pool is associated with macroaggregation and is controlled by soil aggregation, soil structure, and mineralogy. The very slowly oxidizable pool is related to soil microaggregation and is controlled by water-stable aggregation. Clay mineralogy and microbial interactions influence the recalcitrant or passive organic C pool. Table 1 shows comparative amounts of these organic pools as related to common soil Orders on the Des Moines Lobe. The dominant organic pool expected for soils on the Des Moines Lobe is the active pool, and lowest pool is the passive pool.

Table 1. Relative Amounts of C Pools in Common Soil Orders on the Des Moines Lobe (derived from Eswaran et al., 1995).

Order	Active Pool	Slowly Oxidizable Pool	Very Slowly Oxidizable Pool	Passive
Mollisol	Dominant	Moderate	Low	Detectable
Histosol	Dominant	Moderate	Low	Detectable
Entisol	Dominant	Moderate	Low	Low

Radiocarbon studies have show that organic C age is greater in B horizons than surface A horizons (Anderson, 1995). Reduction of organic C contents due to cultivation results in increased mean age of C in Ap horizons. Mean age of C in humic substances is commonly greater in finer soil fractions. Slower processes for C accumulation and reduced composition pressure, which enhance longer turnover times, are influential in lower organic C pools in B horizons. Older C pools in Ap horizons suggest the biologically active and the labile pools decompose preferentially and the resistant and passive pools are more concentrated. Older C forms in the finer soil fractions suggest more humified materials and microbial processing of humus in clay rather than fine silt or coarse silt fractions (Anderson, 1995).

The composition of vegetative material influences microbial transformations. Six common groups of vegetative materials are cellulose, hemicellulose, lignin, water-soluble fractions, ether/alcohol soluble constituents, and nitrogenous/sulfurous proteins (Alexander, 1977). The bulk of plant material consists of cellulose, hemicellulose, and lignin. The decomposition of plant materials undergoes numerous processes and interactions. Microorganisms initially break down first plant materials, carbohydrates, and protein, with C evolved as CO_2 (Anderson, 1995). Remaining C is subsequently assimilated and converted into microbial tissue and corresponding metabolites. Next, there is the concentration of recalcitrant (passive) C as aliphatic and aromatic C structures. The microbial degradation of lignin molecules and the reduction of aromatic C characterize continued decomposition. Microbial synthesis of humic materials and the generation of alkyl C fractions typify long-term decomposition. Biological recalcitrance of humic substances are due to the chemical structure of the humic material, the influence of clays on surface adsorption and physical protection, and the inaccessibility through protection within microaggregates and the lower turnover rates in subsoil horizons.

Two important functions of organic matter decomposition are serving as an energy source for microbial growth and as a C source for cellular tissue formation (Alexander, 1997). Energy and C sequestration are critical components for the microflora. Numerous processes can occur during organic matter decomposition. Carbon can be assimilated by conversion to protoplasmic C. The efficiency of assimilation is influenced by the chemical composition of the organic substrates. Inefficient microbial populations lose most of their C as wastes and form little cellular material. Anaerobic populations assimilate C inefficiently by leaving substantial carbonaceous products in the soil and releasing little energy in the original organic material. Efficient microbial populations, such as aerobic microorganisms, release less C and organic products, with most of the C incorporated into cellular material. Regardless, the ultimate C incorporated into cellular material eventually becomes decomposed.

Soil Landscape Relationships on the Des Moines Lobe

The Des Moines Lobe is a physiographic region hosting many soil series in the Mollisol, Entisol, Alfisol, and Histosol orders. The landscape is of glacial origin, and rolling till deposits typify the prairie pothole region. Groundwater is an important factor in sustaining the prairie pothole region. Basins are classified as recharge, discharge, and throughflow (National Research Council, 1995). Recharge basins lie above the groundwater and accumulate surface water, which recharges the underlying groundwater. Throughflow basins are characterized by seepage from groundwater but lose the water back to groundwater on lower end of the groundwater gradient. Discharge basins receive upwelling groundwater seepage and lose their water mainly by evapotranspiration. Soils in these basins are moderately alkaline but some discharge basins are highly saline and marked by a ring of salt deposits around the margin of the basin depression. Parent material and hydrology influence the waterflow and nutrient characteristics in wetlands environments (Figure 6). Wetland vegetation provides useful information regarding hydrology and the physico-chemical environment. It can influence hydrology by evapotranspiration and increasing flow resistance. It influences the soil or sediment physicochemical environment by affecting soil properties, such as organic C content and dissolved oxygen, and traps sediment and accumulates organic matter. The hydrology in prairie potholes can vary yearly (Figure 7). Driest months occur in summer and midfall seasons during dry and wet seasons (National Research Council, 1995; Steinwand and Fenton; Khan and Fenton, 1994; and James and Fenton, 1993).

The Des Moines Lobe represents the last advance of the Late Wisconsin stage approximately 14,000 YBP. This landscape has four major end moraines that are separated by broad areas of low relief, undulating topography, and poor internal drainage. Numerous rapid advances southward and subsequent ice stagnation deposited a distinct complex array of landforms and supraglacial sediments, such as interlayered diamictons and sorted sediments, over loam-textured glacial till. Supraglacial deposits reflect a deposition from ice wasting, whereas the glacial till represent subglacial deposition. Water influences the soil and landscape genesis where closed depressions represent areas along the landscape with accumulation of organic material from adjacent soils and open depressions represent areas along the landscape with an outlet to remove eroded sediment.

Soil Glacial Stratigraphy and Hydrology on the Des Moines Lobe

Nature of the parent material influences wetland status, spatial variability, and microbial processes. Burras and Scholtes (1987) studied basin properties and postglacial erosion rates of two minor moraines in the Des Moines Lobe. Three strata characteristic of low relief minor moraines were dense Late Wisconsin basal till, coarse diamicton, and locally derived fine-grained sediment. The basal till is buried under the locally derived postglacial sediments. The till also has relatively higher bulk densities and uniform loam textures (approximately 17% clay and 45% sand) than overlying postglacial sediments and coarse diamictons. The till was found to parallel the current surface topography. The diamicton is poorly sorted sediment of sand or coarser thinly distributed through the fine-grained matrix. The diamicton has loose consistency with textures ranging from sandy loam to loamy sand (55-70% sand). The diamicton was found to be absent or thin on slopes

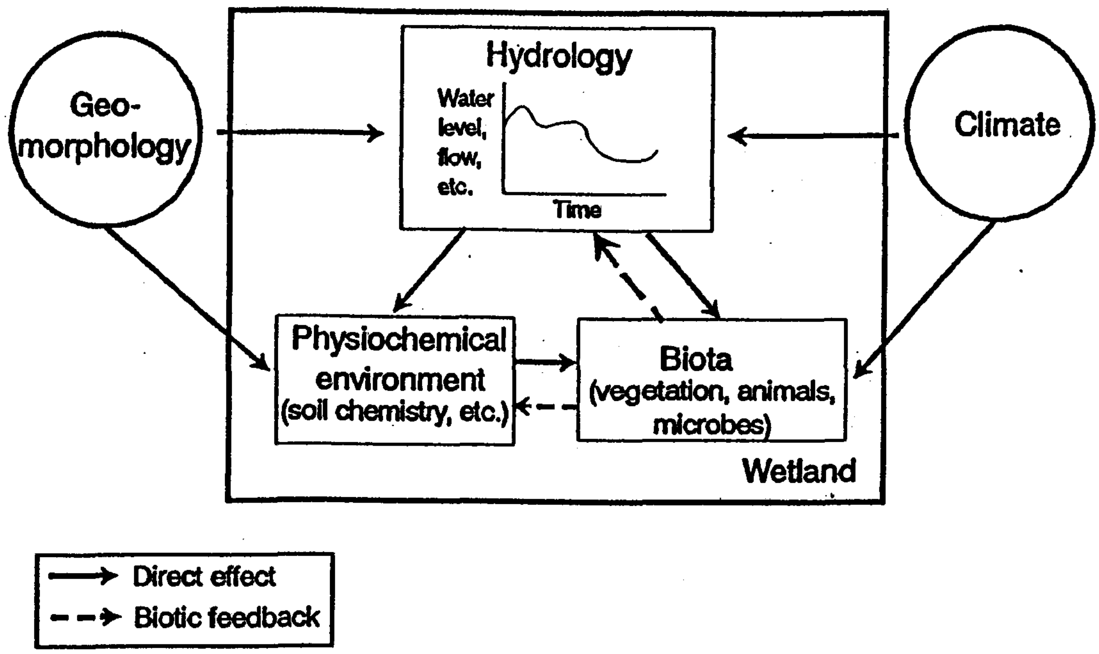

Figure 6. Hydrology interactions in wetlands (National Research Council, 1995).

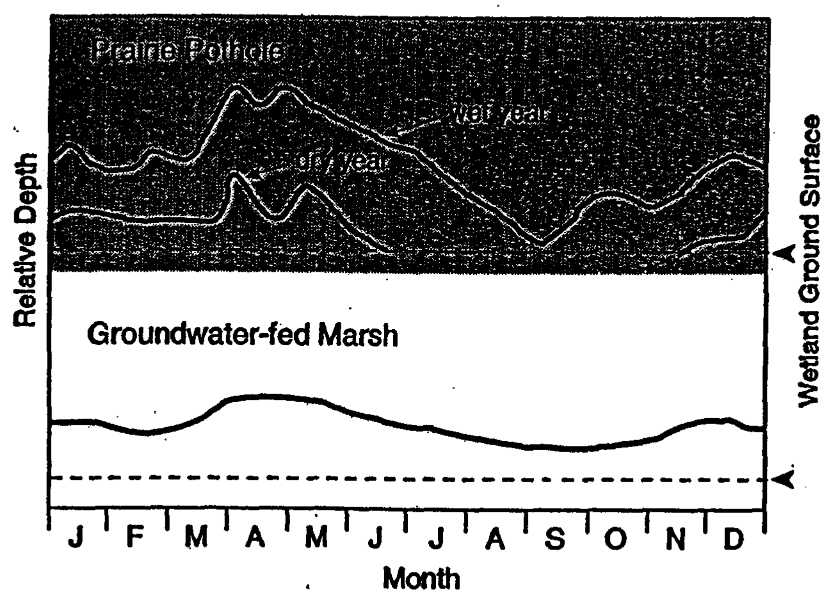

Figure 7. Water table fluctuations in prairie potholes (National Research Council, 1995).

thickening to the base of the basin, reflecting either postglacial incision into the till or a coarse supraglacial mantle deposited during ice wasting. The postglacial fine-grained sediment represented transported sediment of finer textures (30% clay and 25% sand). This sediment was present in the basin center due to sediment sorting during transportation. Common properties of the sediment included lower bulk densities, increased clay and silt content, relict soil structure, and discontinuities to basal till like stonelines, deposits of coarse diamicton, and variations in soils consistency. The authors also reported nonuniform rate of Holocene erosion and soil genesis under four periods of stabilities:

a. Early period of instability
b. Early period of stability
c. Late period of instability
d. Late period of stability

Steinwand and Fenton (1995) identified three strata of surficial sediments overlying the glacial till (Figure 8). Two upper strata of surficial sediment were slope alluvium deposited approximately after 4300 YBP and were labeled Facies 3 and 4. A lower stratum resembling alluvium from supraglacial sediment subsequently eroded from adjacent upslopes was labeled Facies 2. Common morphological properties of Facies 3 include sandy loam to silt loam textures, frequent stratification with alternating 2-4 cm thick beds of silt loam-very fine sandy loam-sand, silt maximum at the base of sediment, and Fe and Mn concentrations along bedding planes. Facies 4 contained clay loam to silty clay loam textures and Fe-depleted matrices, rare Fe and Mn concentrations, and provided the parent material for commonly poorly drained soils on the Des Moines Lobe. Facies 2 consisted of stratified sand to sandy loam in swales, fining upward of mean particle sizes, variable color, and very rare Fe and Mn concentrations. The underlying till consisted of two zones. One zone was a subglacially deposited unit with an upper oxidized-reduced weathering zone and a lower unoxidized weathering zone. The second zone represented a rare unit of variable texture and weak stratification. This unit was restricted to summit slope positions. The oxidized-reduced weathering

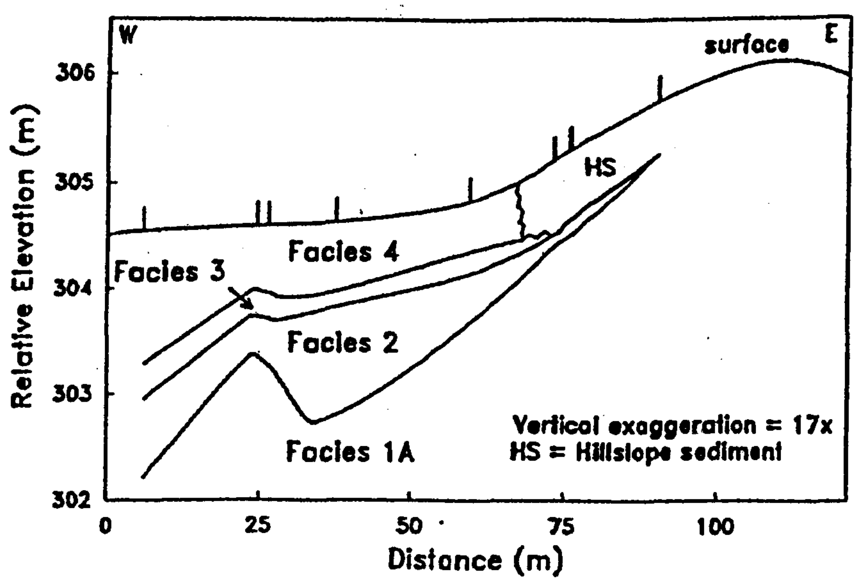

Figure 8. Stratigraphic cross sections of postglacial sediment (Steinwand and Fenton, 1995).

zone contained loam textures, massive to moderate platy like structures due to horizontal fractures, redoximorphic features as pore linings on fractures and masses adjacent to the fractures. The unoxidized zone contained loam textures, dark-gray matrices, massive structures, rare fractures, and few redoximorphic features in fractured pore linings. Groundwater flow was predominantly lateral from the topographic highs toward the adjacent lows. The authors suggested the stratigraphy of the postglacial sediment and weathering zone of the underlying till promoted the flow regime. The hydrology was thus characterized as recharge on topographic highs, lateral groundwater flow on sideslopes, and discharge in swales.

Walker (1966) reported five stratigraphic zones for bogs on the Des Moines Lobe. A close relationship between pollen profiles and stratigraphy changes denoted the kind of deposition in the bog was related to the kind of vegetation within the basin. A historical framework for soils and landscapes in Iowa was developed. The first post-Cary Interval occurred from 13000 to 10500 YBP and represents the initial erosion phase of the till surface. This phase was represented by the lower silt zone where organic matter contents were low and vegetative cover was scarce. The initial postglacial vegetation was dominantly coniferous in a cool climate. The conditions favored more rapid erosion (0.9 tons/acre/yr.) and landscape instability. The lower muck zone represents the first stage of landscape stability. It was dated to occur from 10500 to 8000 YBP. The vegetation changed from conifers to mixed forest with predominantly hardwood species in a warming climate. The upper silt zone represented an interval from 8000 to 3000 YBP during which vegetation and landscape changed. Hillslopes were reduced significantly with most of the soils developed prior to 8000 YBP being eroded away. The landscape instability probably resulted from a sudden change in climate. This resulted in the depletion of existing vegetative cover and exposure of the soil surface to erosion. The climate in this period is characterized as dry and warm, supporting prairie vegetation. The prairie vegetation restablilized the landscape at 3000YBP where erosional rates were reduced to approximately 0.1 tons/acre/year. The upper muck zone represents environmental conditions where a prairie system exists with oak forest invading. Walker (1966) reported the landscapes on the Des Moines Lobe are younger than 8000 YBP with most of the soil features related to the prairie environment developed during the last 3000 years of landscape stability. Soils on upper landscape positions, such as Clarion and Nicollet soils, formed in prairie environments whereas many soils on the lower landscape positions, such as Webster and Harps, developed their upper sola from the surficial sediment. The profile properties of soils on lower landscapes are related to the last 3000 years of prairie environments.

James and Fenton (1993) found soil morphology and water table depth and duration were highly correlated for Aquolls in undrained traverses but were poorly correlated in drained ones. Webster, Canisteo, Harps, and Okoboji soils in both traverses had endosaturation; contained redoximorphic features as mottles, and met hydric soil requirements. The Okoboji soil in the undrained traverses qualified as a wetland based on vegetation and hydrology. The Webster, Canisteo, and Harps soils in the undrained traverse met farmed wetland classification. Webster, Canisteo, Harps, and Okoboji soils in drained traverses classified as prior converted farmland. The authors reported Clarion soils are forming in an environment dominated by oxidation reactions with artificial drainage not greatly affecting pedogenesis. The remaining soils on the landscapes were reported to be forming in moisture regimes different from their original state, and their corresponding upper sola represent a relict feature distinct to present soil environment.

Khan and Fenton (1996) reported secondary Mn and the ratio dithionite-extractable Mn and Fe at different depths could be useful indicators of oxidation and reduction conditions of soils on the Des Moines Lobe. They reported decreases in total Fe with saturation. Citrate-bicarbonae-dithionite (CBD) extractable Fe and Mn decreased with permanent saturation. CBD-Mn increased in areas of periodic saturation. The water table was found to fluctuate most in soils on higher landscape positions. This fluctuation promoted the rapid oxidation of Fe oxides in the absence of organic matter and a slower rate of Mn deposition. Reduced iron may have occurred from the shallow water table and the longer periods of saturation on lower landscape. The reduced iron may also have complexed with organic matter during discharge and limiting movement downward during recharge periods. When the water table depth decreased, the soil redox potentials on the lower slopes were high enough to favor formation of Mn oxides rather than Fe oxides.

Water table depth was found to be a function of annual precipitation and landscape position (Khan and Fenton, 1994). Soils on toeslopes and depressions (Aquolls) had the shallowest water table, the longest time of saturation, and B horizons with gray matrices, bright mottles, and Fe-Mn concretions. Backslope soils (Nicollet series, eg) had intermediate indication of wetness. Recharge was the dominant process for soils on higher landscape positions. Ephemeral recharge and discharge of groundwater dominated for soils on the lower landscapes. Changes in color hue from 10YR in well-drained soils to 2.5Y in somewhat poorly drained soils to 5Y in poorly drained soils reflected the removal of free iron at lower depths (Khan, 1991). Smectite was the dominant clay mineral in all the soils of the catena. Kaolinite and mica were present in smaller amounts in these soils. Soil on lower landscape positions, such as the Canisteo and Knoke series, displayed lithological discontinuities. The soils on upper landscape positions, such as the Clarion and Nicollet series, represented soils relatively more weathered with noncalcareous sola and a greater depth to free carbonates. Soils on lower landscape positions formed on relatively younger fine-grained sediment overlying the glacial till in the Mollisol catena.

Table 2. Soil Classification of Diagnostic Soil Series on the Des Moines Lobe, Iowa.

Soil Series	Drainage	Soil Classification
Clarion	Moderately Well	Fine-loamy, mixed, superactive, mesic Typic Hapludoll
Nicollet	Somewhat Poorly	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll
Webster	Poorly	Fine-loamy, mixed mesic Typic Endoaquoll
Canisteo	Poorly	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll
Okoboji	Very Poorly	Fine, smectitic, mesic Cumulic Vertic Endoaquoll
Harps	Poorly	Fine-loamy, mixed, superactive, mesic Typic Calciaquoll
Wacousta	Very Poorly	Fine-silty, mixed mesic Typic Endoaquoll
Palms	Very Poorly	Loamy, mixed, euic mesic Terric Haplosaprist
Storden	Well	Fine-loamy, mixed, superactive, mesic Typic Eutrudept

Common Soil Series

Clarion soils are fine-loamy, mixed, superactive, mesic Typic Hapludolls (Table 2). They are moderately well drained and moderately permeable soils on uplands (Dewitt, 1984). These soils formed in calcareous glacial till under native prairie vegetation. They commonly are located on the upper landscapes on summit or shoulder positions. The thickness of the mollic epipedon ranges from 25-45 cm. The thickness of the solum and depth to carbonates vary and range between 45-125 cm. Soil colors of the mollic epipedon are black (10YR 2/1) to very dark grayish brown (10YR 3/2). Soil textures range from loam to silt loam of high sand content. Soil color in the subsoil is brown (10YR 4/3) to dark yellowish brown (10YR 4/4). Textures in the subsoil are typically loam, clay loam, or sandy loam. The solum exhibits neutral to slightly acid soil reactions. The C horizon is lighter in color with colors of yellowish brown (10YR 5/4) to olive brown (2.5Y 5/4). Textures in the C horizon vary from loam, clay loam, to sandy loam.

Nicollet soils are fine-loamy, mixed, superactive, mesic Aquic Hapludolls (Table 2). They are somewhat poorly drained and moderately permeable, occurring on low ridges and slightly concave sideslopes on uplands (Dewitt, 1984). These soils formed in loamy glacial till. The thickness of the solum and the depth to free carbonates range from 50 to 120 cm. The thickness of the mollic epipedon also varies from 30 to 60 cm. The color of the mollic epipedon is black (10YR 2/1) to very dark gray (10YR 3/1). Soil textures in the mollic epipedons range from loam to clay loam. Subsoil horizons are dark grayish brown (10YR 4/2 to 2.5Y 4/2) with loam or clay loam textures. Soil reaction in the solum is common neutral to slightly acid. The C horizon varies in color with mainly 2.5Y hues, values of 5, and chroma of 2 to 4. Textures range from loam to clay loam. Other common morphological characteristics in the solum are mottles in the B horizons and occasional manganese concretions at 20 cm.

Canisteo soils are fine-loamy, mixed, superactive, (calcareous) mesic Typic Endoaquolls (Table 2). They are poorly drained and formed in calcareous local alluvium from till or calcareous glacial till (Figure 9). They occur on nearly level slopes adjacent to Webster soils on higher relief and Okoboji soils on lower depressions (Dewitt, 1984). The sola is mildly alkaline (pH 7.4 to 7.8) and calcareous. Thickness of the mollic epipedon ranges from 30 to 60 cm. Colors of the mollic epipedon are black (N 2/0 to 10Yr 2/1). Textures in the mollic epipedon are silty clay loam to clay loam. The B horizons are gleyed (Bg) with soil color values of 4 to 5 and chroma of 1 to 2. Soil textural classes in the B horizons are either silty clay loam, loam, or clay loam. The C horizon is also gleyed with color values of 5 to 6 and chroma of 2 to 4. The C horizon has textural classes of loam to clay loam but the presence of stratified loam or silty clay loam horizons are possible in the profile.

Harps soils are fine-loamy, mixed, superactive, mesic Typic Calciaquolls (Table 2). They are poorly drained, moderately permeable and highly calcareous (Dewitt, 1984). They commonly occur on rims and low ridges around and between lower depressions in uplands (Figure 9). They formed in local alluvium derived from glacial till and formed under native water-tolerant grass vegetation. The thickness of the mollic epipedon ranges from 25 to 60 cm. Colors of the mollic epipedon range from black (10YR 2/1) to very dark gray (10YR 3/1) or N 3/0). Textures ranged from loam to clay loam in the mollic epipedon. The B horizons are lighter in color with 2.5Y or 5Y hue notations, 5 to 6 values, and chroma of 1 to 2. Soil textures in the B horizons range from loam, clay loam, or sandy clay loam. C horizons are gleyed with loam and sandy clay loam textures. The sola reaction is moderately alkaline. Harps soils commonly are adjacent to Canisteo and Okoboji soils on the landscapes. Common morphological features include few snail fragments in the mollic epipedon, secondary carbonate accumulations as thread or concretions in the B horizons, and fine olive (5Y 5/6) mottles and brown (7.5YR 5/6) Fe accumulations or oxides in the B and C horizons.

Okoboji soils are fine, smectitic, mesic Cumulic Vertic Hapludolls (Table 2). The soils are very poorly drained with moderately low permeability (Dewitt, 1984). Okoboji soils occur in upland depressions with slopes of 0-1%. They formed in local alluvium washed from adjacent uplands (Figure 9). Neighboring soils include Canisteo and Harps soils. The thickness of the mollic epipedon varies from 60-90 cm. Depth to carbonates also varies from 50 to 125 cm. Moist colors of the mollic epipedon are black (N2/0 to 10YR2/1). Textures in this diagnostic horizon ranges from silty clay to mucky silt loam. The B horizons are gleyed with moist colors of 2.5Y or 5Y hues, values of 4-5, and chroma < 2. Textures in the B horizons are commonly silty clay loam. Sola reaction is neutral to moderately alkaline. Underlying C horizons are also gleyed with a calcareous silty clay loam texture and mildly to moderately alkaline sola reaction. Thin strata of loam can be present. Common morphological features in Okoboji soils include thick black (cumulic) mollic epipedons, fine yellowish brown (10YR5/4) and strong brown (7.5YR5/6) mottles in the B and C horizons, and secondary carbonate accumulations and organic krotovinas in the B and C horizons.

Klossner soils are Histosols on landscapes on the Des Moines Lobe. The soils are classified as loamy, mixed, euic, mesic Terric Haplosaprists (Table 2). They are very deep and very poorly drained soils formed in well decomposed organic material overlying moderate to moderately slow permeable glacial materials. They occur on basins that were formerly lakes or ponds, lake plains, floodplains, or moraines. The vegetation was herbaceous prairie plants tolerant to wet conditions. The thickness of the O horizons ranges from 40 to 125 cm. Thickness of underlying A horizon ranges from 20 to 115 cm. The solum reaction is commonly slightly acid to moderately alkaline. The organic horizons have moist chromas of 0 to 2, values of 2 or 3, and hues of 10YR, 2.5Y, and 5Y. The 2A horizons have moist hues of 10YR, 2.5Y, 5Y and , values of 2 to 3, and chromas of 0 to 2. Textures vary from loam, silt loam, sand clay loam, silty clay loam, or clay loam. Moist hues of the C horizon are variable ranging from 10YR, 2.5Y, 5Y, or 5GY. Moist chroma ranges from 0 to 2, and moist values range from 2 to 7. Textures vary from loam, silt loam, sand clay loam, silty clay loam, or clay loam in the C horizons.

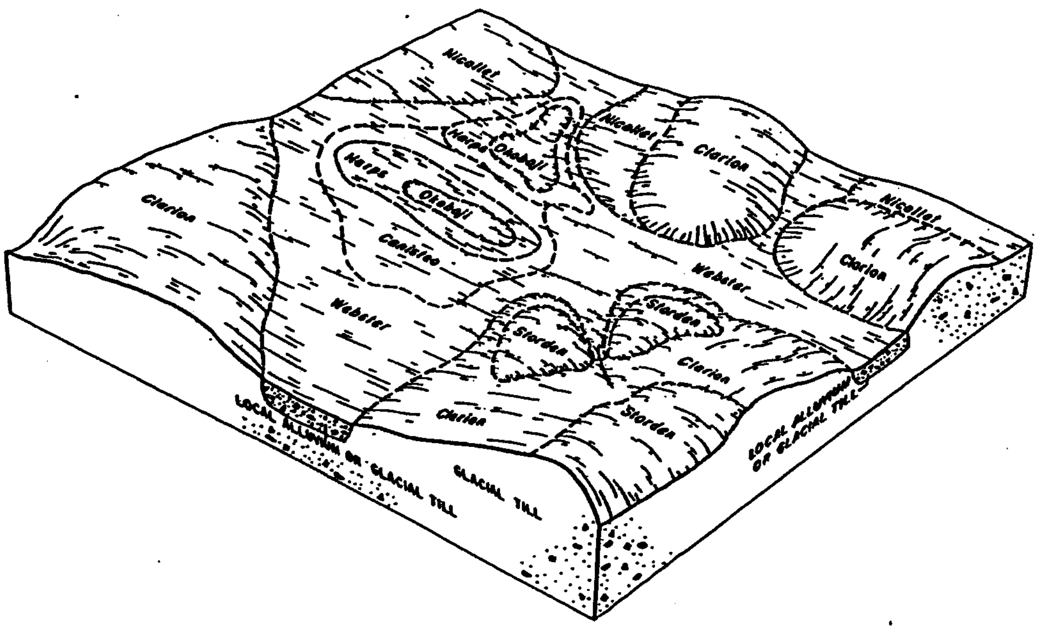

Figure 9. Clarion-Nicollet-Webster soil association (DeWitt, 1984).

Pedogenesis of Histosols

Hydrology is a significant factor for the pedogenesis of Histosols (Buol et al., 1995; National Research Council, 1995). Organic matter accumulation occurs in these soils on closed or open basins. The closed basins exhibit organic matter accumulation when precipitation exceeds outflow and level topography develops slow free waterflow or surface drainage. Continuous organic matter deposition with time results in the filling of the closed depression with slowly decomposed organic matter, resulting in the basin to no longer function. Open basins can contain Histosols when a localized topographic feature restricts water movement and allows local accumulation of organic matter. This overall process represents the terrestrialization of former lakes and ponds. Decomposition rates influence organic matter accumulation and are directly connected with soil or sediment temperature. Other significant pedogenic/geogenic processes are also involved in Histosol formation. Paludification is the initial geogenic accumulation of organic matter in anoxic conditions created by prolonged saturation and reduced oxygen infusion into the soil environment for organic matter oxidation. The decomposition of the organic matter is influenced by moisture content, temperature, deposit composition, acidity, microbial activity, and importantly time. Ripening is another process in Histosol genesis. It involves chemical, physical, and biological changes of the organic material after exposure of oxygen in water saturated conditions. Chemical ripening involves the chemical decomposition of the organic materials and the partial conversion of the constituents to intermediate complexity and the eventual formation of highly resistant humus. Biological ripening consists of the decrease in particle size, the mixing of organic materials, and the development of peds and other pedological features (Krotovinas) by organisms.

Pedogenesis of Mollisols

The dominant pedogenic process in Mollisols is melanization (Buol et al., 1995). Melanization is the darkening of the soils by addition and decomposition of organic matter in the mineral soil forming dark mollic epipedons characteristic of Mollisols. Melanization involves various specific subprocesses. These include root extension into the soil profile, microbial decomposition of the organic materials, mixing of organic and soil material by microorganisms (humification), illuviation/eluviation of organic and mineral colloids along soil voids between peds, and formation of stable resistant humic substances of ligno-protein composition. Cumulization involves the overthickening of mollic epipedons downslope as a result of erosion and transportation upslope. Along a glacial landscape, a sinouos relationship exists between soil and sediment relationships with slope position (Gerard, 1992). Fenton (1983) reported there were four sequences in textural differentiation of Mollisols: leaching of carbonates, clay formation, chemical alteration of clay minerals, and clay translocation. The continuous cycles of soil genesis formed numerous kinds of soils distinguishable largely by differences in parent material, texture, carbonate status, and moisture regime, and controlled by previous erosion-deposition processes and the surface hydrology. Therefore, considerable variability in soil chemical, microbial, and physical properties exists in these landscapes. Little information exists elucidating the source of soil variability and understanding the influence of restoration on soil quality in these restored hillslopes. The objectives of this research were:

1. To study and model the changes in soil hydromorphology along restored prairie-wetland hillslopes in the Des Moines Lobe region.
2. Elucidate the variability of soil properties in mollic epipedons on restored prairie-wetland hillslopes.
3. To develop set of reference point for long term monitoring of soil C and other soil quality indicators of restored prairie-wetland hillslopes.
4. To quantify and assess the variability of soil microbial biomass in mollic epipedons on restored hillslopes.

Explanation of Dissertation Format

This dissertation is presented in four chapters written in the alternate format. Chapter 1 is a general introduction providing a broad discussion on wetland traits and biogeochemistry and soil landscape relationships in the Des Moines Lobe region. Chapter 2 to 4 are complete journal manuscripts modified to conform to Iowa State University dissertation requirements. Each chapter has its own abstract, introduction, materials and methods, results and discussion, and summary or conclusion, and reference cited. The dissertation also includes a general summary integrating the major findings in this study and an appendix providing additional data not used in the dissertation.

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CHAPTER 2: SOIL LANDSCAPE RELATIONSHIPS ON RESTORED PRAIRIE-WETLAND HILLSLOPES IN CENTRAL IOWA: SOIL HYDROMORPHOLOGY

A paper to be submitted to the Soil Science Society of America Journal

L. P. Moran and T.E. Fenton

Abstract

Understanding the influence of restoration practices on previous cultivated lands requires studying the effects of past disturbances and the subsequent effects on hydrology and soil quality. This study was conducted to monitor water tables and soil morphology in restored prairie-wetland hillslopes in central Iowa. Three wetlands under different restoration times (8-15years) were selected for detailed study on the Des Moines Lobe. Water monitoring wells were installed along eight undrained hillslopes and one ditch-drained hillslope. Water table depths were measured from May 2000 to June 2002. Four general groups were developed to describe soil hydromorphology along the restored prairie-wetland hillslopes. Soil morphology was correlated with hydrology for all groups on the restored hillslopes. Soil morphology was correlated with local hydrology on backslopes to toeslopes in the drained hillslope. Group I included Clarion and Nicollet soils on upland prairie summits. Recharge is the dominant hydrologic process in the group. Soil classification for group I was fine-loamy, mixed, superactive, mesic Typic/Aquic Hapludoll. Mean annual water table depths ranged from 130 to 189 cm below the soil surface. Shallowest water table depths ranged from 5 to 130 cm below the soil surface. Group I soils had dark moderately acidic loamy mollic epipedons overlying thick slightly acidic clay loam Bw horizons with high and low chromas. Bw horizons overlie thin clay loam Bg horizons, if present. Redoximorphic features were restricted to Bg and Cg horizons in group I soils in undrained hillslopes. Group I soils in the ditch-drained hillslope had relict redoximorphic features in the lower sola and Cg horizons. Group II soils included Delft and Webster soils on upland prairie-backslopes. Soil classification was fine-loamy/silty, mixed, superactive, mesic

Typic/Cumulic Endoaquoll. Mean annual water table depths ranged from 64 to 158 cm below the soil surface. Shallowest water table depths ranged from 3 to 76 cm below the soil surface. Group II soils generally had black cumulic moderately/slightly acidic mollic epipedons overlying neutral/ slightly alkaline Bg horizons. Group III soils included Canisteo and Delft soils on wet prairie or sedge wetland footslopes. Soil classification was fine-loamy/silty, mixed, superactive, calcareous, mesic Typic/Cumulic Endoaquoll. Mean annual water table depths ranged from 35 to 93 cm below the soil surface. Mean water table depths did not parallel the surface topography in the group, reflecting the consumptive water use by the hydrophytes and phreatophytes in these vegetative zones. Group II and III soils varied in type of redoximorphic feature present and the depth to redoximorphic features. In general, lower A horizons had low chroma mottles or pore linings. The Bg horizons had low chroma mottles, high chroma mottles or a combination of both. Group IV soils included dominantly Okoboji soils on closed pond depressions. Soil classification ranged from fine/fine-loamy/fine-silty, mixed or smectitic, (superactive), mesic Cumulic Vertic Endoaquolls. Mean annual water table depths ranged from 35 cm above the soil surface to 41 cm below the soil surface. Group IV soils had shallow depths to redoximorphic features. Sola had a mixture of low chroma mottles, high chroma mottles, and low/high chroma pore linings. Longer term monitoring of water tables is required to better understand soil hydromorphic relationships and variability.

Introduction

Hydric soils are integral components of the landscape in Iowa. The majority of the soils has been drained and put into cultivation, commonly corn and soybean rotations. Cultivation and drainage have altered these soils resulting in a new quasi-equilibrium with the current environmental conditions. Increased awareness of the economic and environmental values of wetlands has resulted in numerous areas of cultivated land being converted back to prairie and wetland ecosystems, especially on the Des Moines Lobe. Hydrology, extent and nature of hydric soils, and vegetation are important factors in the proper functioning and maintenance of wetland ecosystems (Wangpakapattanawong, 1996). Wetlands serve numerous purposes, such as trapping sediment and water, improving groundwater quality, serving as sinks for carbon, habitats for wildlife, and sorbing contaminants from adjacent sites. Water is significant on these landscapes as it serves as an energy source in landscape and soil processes, such as erosion, carbon sequestration, vegetative proliferation, leaching and movement of soluble and mobile inorganic and organic compounds. The nature of the parent material is also important in influencing the wetland status, hydrology, soil genesis, and spatial variability. Drainage removes excess water and lowers the water table in the solum, increasing aeration in the upper solum and influencing soil processes such as redox reactions and microbial activities.

The relationship between soil saturation and color, presence and type of redoximorphic features, and landscape position has been well documented. Previous studies related aquic soil conditions to gray colors and low chromas (<2) in the solum, and soil morphology best expressed on footslope and toeslope positions (Evans and Franzmeier, 1986; Richardson and Daniels, 1993; Khan and Fenton, 1994; Pickering and Veneman; 1984; Franzmeier et al., 1983; Veneman et al., 1998; Jacobs et al., 2002; James and Fenton, 1993; Steinwand and Fenton, 1995). The presence of redoximorphic features, such as mottles, is related to the depth of the seasonal high water table during the growing season. The presence of Fe depletions or gray or reduced matrix indicates significant duration of saturation (Veneman et al., 1998).

More long-term detailed studies are needed to better assess the relationship between soil morphology and hydrology in Mollisol landscapes on the Des Moines Lobe. James and Fenton (1993) studied water tables in a paired artificially drained and drained catena on the Des Moines Lobe, Iowa. They found that morphological properties and water table depth and duration were highly correlated for the Aquolls in the undrained catena but were not in the artificially drained catena. Soils on upper backslopes to toeslopes (poorly drained to very poorly drained) of the drained and undrained catenas were endosaturated, had redoximorphic features, and met criteria for hydric soils. Soil morphology in the upper sola of soils on the upper slope positions represent relict conditions unrelated to the present soil environments. Khan and Fenton (1994) studied the relationship between soil saturation and morphology in a drained Mollisol catena on the Des Moines Lobe. They found that the depth to the water table, duration of saturation, soil morphology, and recharge and discharge to the groundwater varies with landscape position. Aquolls had the shallowest water table, longest time of saturation, gray B horizons, bright redoximorphic concentrations, and Fe-Mn concentrations. Soils on upper slope positions were not saturated, had B horizons with high chromas without redox features, deeper water tables, and maximum fluctuation of water table levels. Thompson and Bell (1996) reported the most significant change in soils across Mollisol catenas in Minnesota is the thickening and darkening of A horizons, which may mask morphological features associated with Fe and Mn transformations and translocations in the upper solum. The same trend was observed in previous soil hydromorphology studies on the Des Moines Lobe.

Despite these published studies, little long-term information exists relating soil water table depths and duration to soil morphology in restored ecosystems. The majority of the studies assess hydrology in landscapes and soils altered by drainage. The dominant morphological property in Mollisol landscapes is the mollic epipedon. The mollic epipedon is a relatively thick (> 25 cm), dark (moist Munsell color value ≤3 and chroma ≤3) surface horizon, with high base saturation (≥50%) and high soil organic carbon (SOC) content (≥0.6 %) (Thompson and Bell, 2001). The formation of mollic epipedons in Iowa landscapes results from the native prairie grass vegetation, which have dense fine fibrous root systems with high rate of annual turnovers. Cultivation has resulted in increased soil erosion, oxidation, and a decrease in mollic epipedon thickness and SOC contents. Restoration of previous cultivated landscapes, especially wetland soils, and hydrology can stabilize the landscape and increase SOC sequestration. The objectives of this study were to i.) quantify water table depths, duration, and variability in restored prairie-wetland hillslopes on the Des Moines Lobe; and ii.) model soil hydromorphology relationships on restored prairie-wetland hillslopes.

Materials and Methods

General Nature of the Research Area

Three wetland sites were selected on the Des Moines Lobe, a region representing the last glacial advance of Late Wisconsinan into central Iowa (Figure 1). Landscapes are characterized as broad, gently rolling, with low-relief and poorly integrated drainage systems. Soil formation has occurred within the last 3000 years (Walker, 1966). Walker (1966) reported that four periods of landscape stability and instability occurred in these landscapes. The recent period of landscape instability, followed by a change in the paleoenvironment to more humid conditions, resulted in the accumulation of mineral sediment in bogs. The stratigraphy of glacial till, weathering zones, and postglacial sediment influence water movement through the landscape. Three strata of surficial sediment overlying till occur in these landscapes. The uppermost two strata represent Late Holocene (4300 YBP) slope alluvium deposited by runoff toward toeslopes and footslopes from adjacent hillslopes. The third lower strata represented Early Holocene slope alluvium derived from coarse-textured supraglacial sediments covering the till and subsequently eroding from adjacent hillslopes

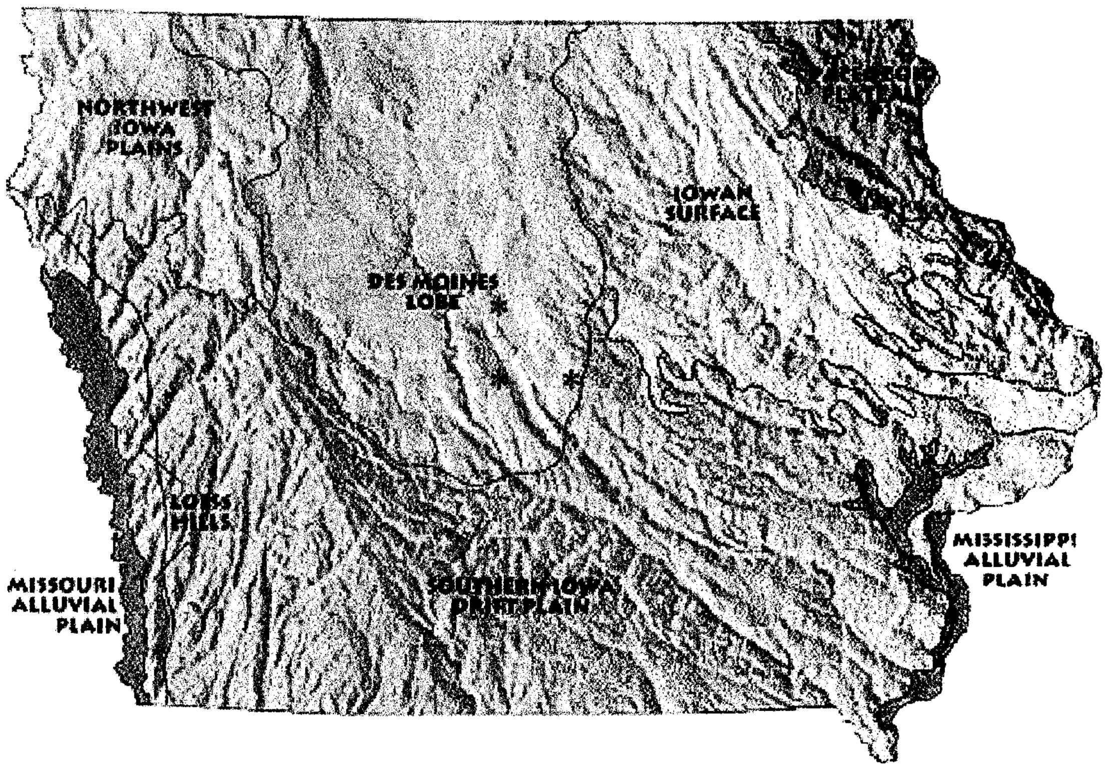

Figure 1. Location of study sites on the Des Moines Lobe.

(Steinwand and Fenton, 1995). Groundwater hydrology in these landscapes is characterized as recharge on topographic highs, lateral groundwater flow on sideslopes, and discharge on swales.

All research sites are greater than 100 ha in size, have different times of restoration, and are managed by the Iowa Department of Natural Resources (Table 1). Upper slope regimes are commonly under prairie restoration and lower slopes under wetland vegetation. Each site varies in mean annual total precipitation with a difference of 110 mm between Colo Bog and Gordon's Marsh. Approximately 75% of the total annual precipitation occurs during the months of April through September for each wetland site (Figure 2). Precipitation data was acquired from the nearest weather stations provided by the National Climate Data Center

Numerous soil associations occur in each of the Iowa counties. Each wetland site is located in different soil associations yet similar patterns of soils occur through out the landscape. The dominant soil association in Gordon's Marsh is the Canisteo-Nicollet-Webster association, which covers 12% of Hamilton County (Dideriksen, 1986). Composition of the association is approximately 35% Canisteo soils, 25% Nicollet soils, 25% Webster soils, and 15% minor soils. The dominant soil association in Colo Bog Complex is the Clarion-Webster-Nicollet soil association, which covers 62% of Story County (DeWitt, 1984). The composition of this association is 35% Clarion soils, 22% Webster soils, 10% Nicollet soils, and 33% minor soils. The dominant soil association of Harrier's Marsh Complex is Canisteo-Clarion-Nicollet soil association, which covers 78% of Boone County (Andrews and Dideriksen, 1981). Soil composition is 29% Canisteo soils, 27% Clarion soils, 14% Nicollet soils, and 30% minor soils. These associations embody nearly level and very gently sloping, poorly drained and somewhat poorly drained, silty and loamy soils that formed in glacial sediments and glacial till. The landscape contains flats with scattered depressions that were formerly marshes and ponds prior to drainage and slopes ranging commonly from 0-3%.

The surface A horizon in Canisteo soils is black (N 2/0), calcareous, commonly with silty clay loam textures, and a thickness of approximately 18 cm. The underlying A horizon is black

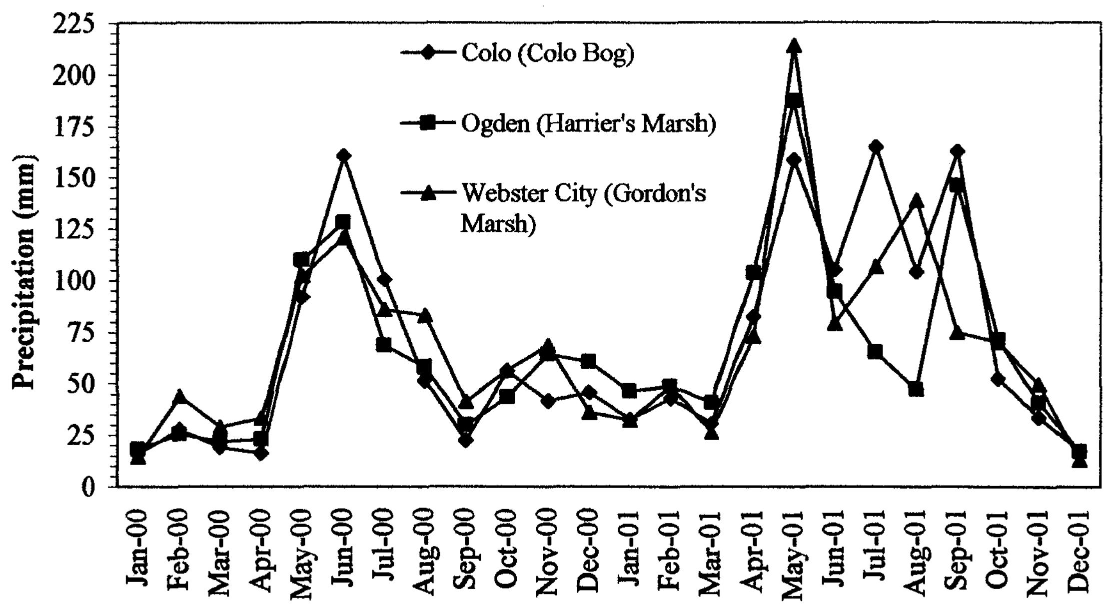

Figure 2. Monthly average precipitation for reseach sites from 2000-2001.

Table 1. Location, county, restoration time, and mean annual total precipitation for research sites.

Wetland Complex	County	Location	Yrs Under Restoration up to 2002	Total Annual Precipitation* Mm
Gordon's Marsh	Hamilton	T.88N. R.26W. Section 33	11	755
Harrier's Marsh	Boone	T.83.N. R.28.W. Sections 5,8	9	850
Colo Bog	Story	T.84.N. R.21W. Section 11	5	865

Gordon's Marsh taken from Dideriksen, 1986; Harrier's Marsh: Andrews and Dideriksen, 1981; Colo Bog: DeWitt, 1984.

to very dark gray, calcareous clay loam horizon with an average thickness of about 30 cm thick. The upper B horizon is typically grayish brown, calcareous, clay loam. The lower B horizon is light olive gray mottled clay loam. Canisteo soils are poorly drained and moderately permeable soils on flats, swales, depressions, and low gradient drainageways on uplands. These soils formed in glacial sediment under native prairie grasses. Mollic epipedon thickness in typical Canisteo soils ranges from 36 to 60 cm. The solum is mildly to moderately alkaline with clay contents ranging from 28 to 35%. C horizons are olive gray, mottled, calcareous loam to a depth of 150 cm. These soils are classified as fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls. Land capability classification for Canisteo soils is IIw.

The upper A horizon in typical Webster soils is black silty clay loam with an average thickness of 20 cm. The lower A horizon is also black silty clay loam with an average thickness of 20 cm. The upper B horizon is typically dark gray and olive gray silty clay loam, and the lower B horizon is mottled, light olive gray clay loam. The C horizons are light olive gray, mottled, calcareous loam to a depth of 150 cm. These soils are poorly drained and moderately permeable and occur on flats, in swales, and in low gradient drainageways. They formed in glacial sediments under native grasses. Thickness of the mollic epipedon in Webster soils ranges from 36 to 60 cm. The solum is neutral to mildly alkaline with clay contents from 28-35%. Classification of Webster soils is fine-loamy, mixed, superactive, mesic Typic Endoaquolls. Land capability classification for Webster soils is IIw.

Nicollet soils are somewhat poorly drained and moderately permeable occurring on low rises and slightly concave side slopes on uplands. They formed in glacial till under native prairie grasses. The upper A horizon is black loam to clay loam with an average thickness of 20 cm. The lower A horizon is commonly black to very dark brown loam to clay loam with a thickness of about 25cm. The upper B horizon is dark grayish brown loam or clay loam, and the lower B horizon is dark grayish brown and brown mottled loam or clay loam. The C horizons to a depth of 150 cm are light olive brown to grayish brown mottled, calcareous loam. The thickness of the mollic epipedon ranges from 25 to 60 cm. The solum is medium acid to slightly alkaline with clay contents of 24 – 30%. The soils are classified as fine-loamy, mixed, superactive, mesic Aquic Hapludolls. Land capability classification for Nicollet soils is I. Clarion soils are well-drained and moderately permeable soils on knobs, ridges, and convex sideslopes in uplands. They formed in glacial till under native prairie grasses. The upper A horizon is commonly black loam 18 cm thick. Subsurface horizons are very dark brown to dark brown loams 28 cm thick. The B horizons are dark yellowish brown loam with a thickness around 45 cm. The C horizons to a depth of 150 cm is yellowish brown, mottled, calcareous loam. These soils are classified as fine-loamy, mixed, superactive, mesic Typic Hapludolls. The minor soils occurring in the soil association are Okoboji, Wacousta, Harps, and Klossner soils. Okoboji soils are very poorly drained and moderately slowly permeable soils on depression on uplands. They formed in glacial or lacustrine sediments under prairie grasses. Okoboji soils are classified as fine, smectitic, mesic Cumulic Endoaquolls. Wacousta soils are very poorly drained and moderately permeable soils in upland basins and depressions. These soils formed in lacustrine sediments under native prairie grasses. Wacousta soils are classified as fine-silty, mixed, mesic Typic Endoaquoll. Klossner soils are Histosols in depressions.

Experimental Field Design and Laboratory Analyses

Three low-relief hillslopes with closed depressions were randomly selected using orthophotos and soil survey maps for each wetland site. Transects were established from the upland summit position to the closed depression (Figures 4-6). Each transect was delineated according to changes in dominance of vegetation (>50% in m^2 plot) and slope position. Slope positions were summit, shoulder, backslope, footslope, and toeslope (Figure 3). Soil cores were sampled to an average depth of 200 cm at points along the landscape with visible changes in vegetation and slope position. Elevation and GPS coordinates were measured at each sampling point. Elevation for each transect was measured by optical distance measurement using stadia

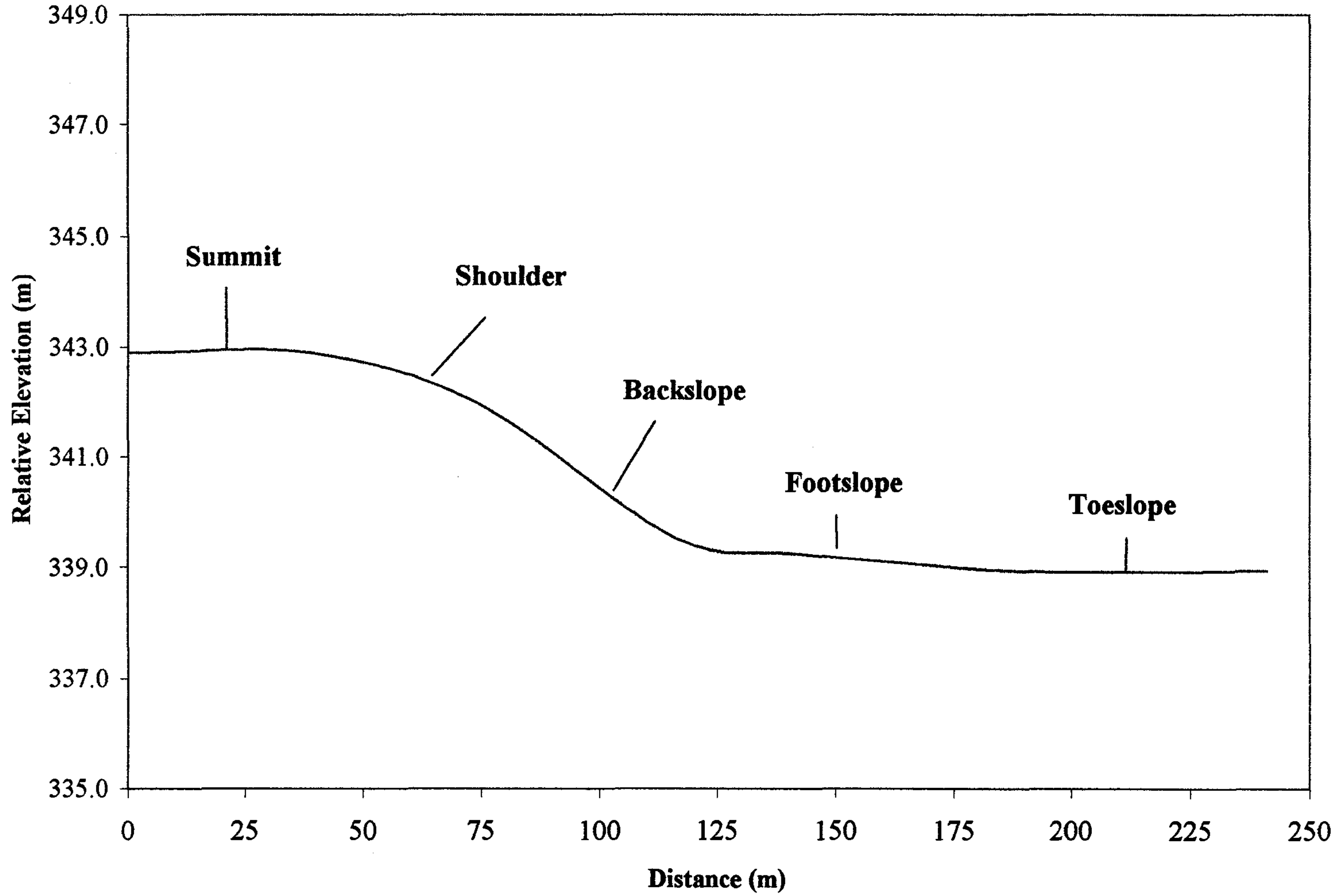

Figure 3. Slope profile on a till hillslope.

Figure 4. Aerial photograph of Colo Bog and location of transects.

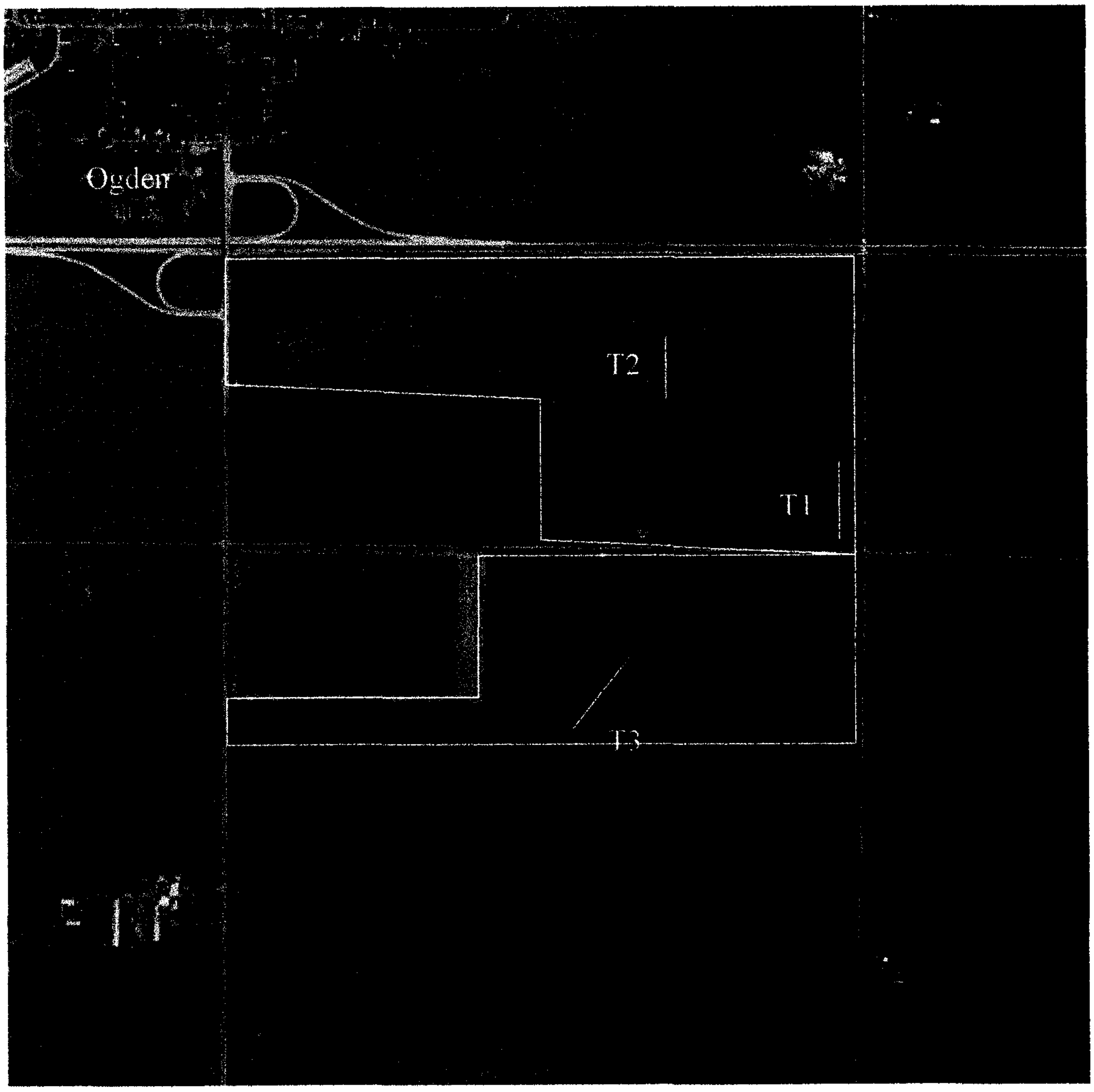

Figure 5. Aerial photograph of Harrier's Marsh and location of transects.

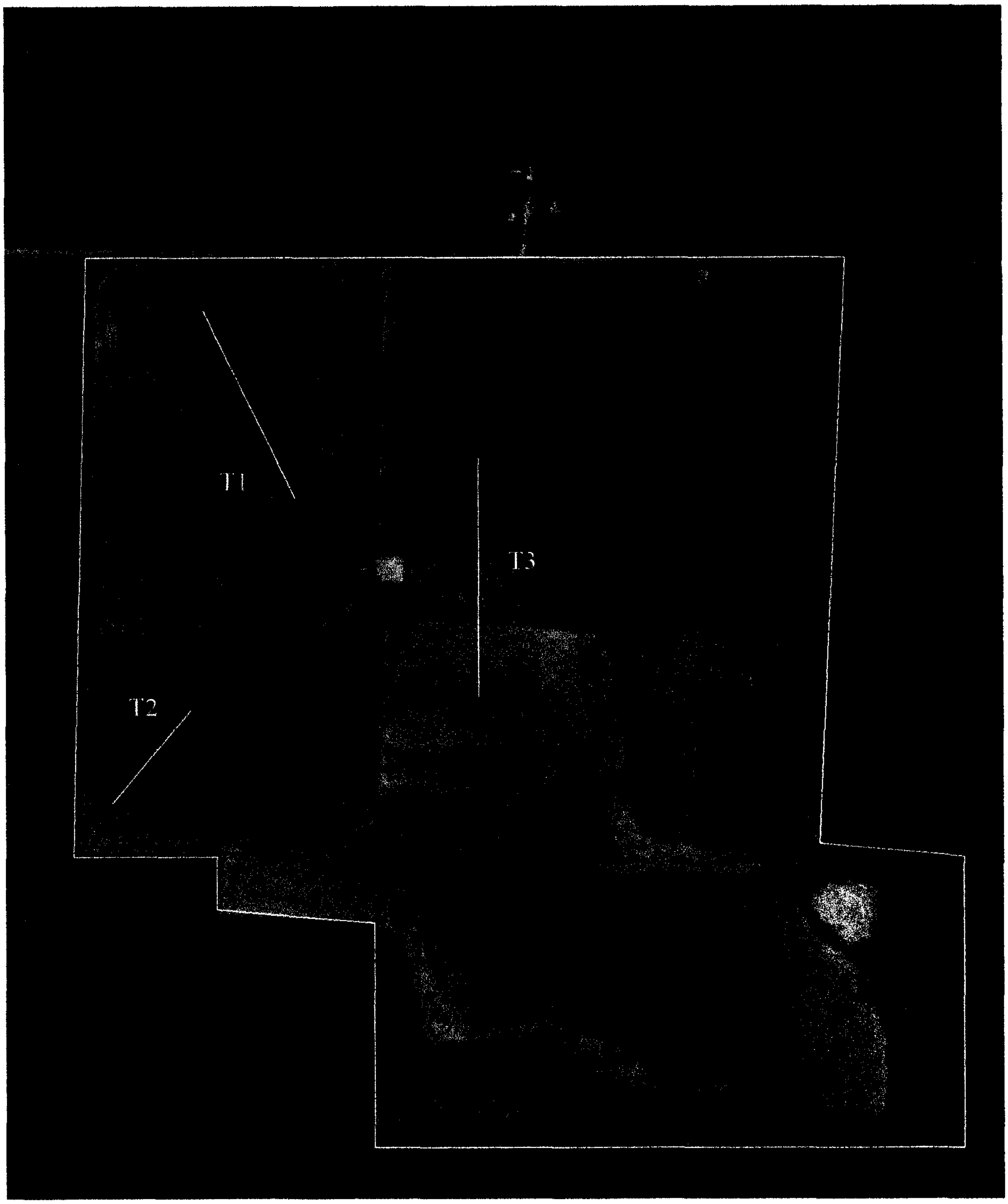

Figure 6. Aerial photograph of Gordon's Marsh and location of transects.

survey equipment. Monitoring wells were installed at each sampling point using perforated polyvinyl chloride tubes sealed at the bottom. Water levels were monitored biweekly to monthly from March 2000 to the present using a battery-powered drop line meter. Monitoring of the wells will be continued to better assess the hydrology in the restored prairie-wetland complex. This study presents water table relationships from May 2000 to August 2002, encompassing a dry and a wet year.

Soil cores were taken to the laboratory and described using standard soil survey procedures (Soil Survey Staff, 1993). Horizon samples of the <2 mm fraction were analyzed for particle size distribution, pH, total carbon (TC), calcium carbonate equivalent (CCE), inorganic carbon (IC), and organic matter (OM). Particle size analysis was determined by the pipette method (Walter et al., 1978). Soil pH was measured with a 1:1 soil/water mixture. Calcium carbonate equivalent was determined using the Chittick apparatus (Boellstroff, 1978). Total carbon was measured by dry combustion in a LECO CHN analyzer. Inorganic carbon was determined from the calcium carbonate equivalent determination. Subtracting the inorganic carbon value from the total carbon value and multiplying by a factor of 1.72 calculated organic matter. Soil descriptions and characterization data for each wetland complex are found in appendices A-C.

Results and Discussion

Hillslope Delineation and Water Table Variability

Table 2 provides general hillslope information for each wetland site. Each hillslope varied in aspect, length, vegetative zones, relief, and number of wells installed. Overall, hillslope relief ranged from 2 to 6 m. Hillslope length ranged from 152 to 306 m. Number of vegetative zones occurring on the hillslopes ranged from 2 to 5. The majority of the hillslopes had north-facing aspects. Twenty-one wells were installed in each wetland site. Number of total wells installed per hillslope ranged from 6 to 8. Eight transects represented restored prairie-wetland hillslopes. Another transect in Gordon's Marsh included a hillslope under different management practice. The hillslope had

Table 2. General transect information for the research sites.

Transect	Aspect	Transect Length m	# Slope Positions	# Vegetative zones/uses	# Wells installed	Hillslope Relief m
			Gordon's Marsh Complex			
1	Northwest	306	5	4	8	3
2	Northeast	241	4	5	6	2
3	South	241	4	5	7	5
			Colo Bog Complex			
1	West	252	5	2	8	6
2	North	152	4	3	6	3
3	East	163	4	5	7	2
			Harrier's Marsh Complex			
1	North	181	5	4	7	3
2	North	159	4	4	7	2
3	Northeast	223	5	3	7	3

summits under alfalfa, forested backslopes, and reed canary grass (*Phalaris arundinaceae*) pond depressions. A drainage ditch parallels the hillslope, influencing the hydrology of the hillslope and allowing for a comparison of management practices on soil processes.

Tables 3-5 show the vegetative zones associated with their landscape element and the dominant species. In general, bluestem-switchgrass prairie occurred on summits and backslopes, wet prairies and sedge wetland zones on footslopes, and wetland ponds on toeslopes. Tables 6-8 show the soil series, natural drainage, and soil classification for each vegetative zone for each hillslope transect. Four groups were developed to describe these landscape relationships:

Group I: Upland prairie soils on summit and shoulder slopes with moderately well and somewhat poor drainage. Dominant soils include Clarion and Nicollet soils with some taxadjuncts. These soils are classified as fine-loamy, mixed, superactive, mesic Typic or Aquic Hapludolls.

Group II. Upland prairie soils on backslopes with poor drainage. Dominant soils are Webster, Delft, and Canisteo soils with some taxadjuncts present. These soils are classified as fine loamy/silty, mixed, superactive, (calcareous), mesic Typic or Cumulic Endoaquolls.

Group III. Wet prairies or sedge wetlands on footslopes with poorly drained soils. Dominant soils are Canisteo and Delft soils with some taxadjuncts present. These soils are classified as fine loamy/silty, mixed, superactive, calcareous, mesic Cumulic or Typic Endoaquolls.

Group IV. Pond depressions on toeslopes with poorly drained and very poorly drained soils. Dominants mineral soils are Okoboji and Glencoe soils. Dominant organic soils are the Klossner soils. Mineral soils are classified as fine/fine silty/fine loamy, mixed/smectitic, mesic Cumulic Vertic Endoaquoll. Organic soils are classified as fine-loamy, mixed, euic, mesic Terric Haplosaprist.

Shallowest water table depths occurred during the months of March to May, the onset of the growing season, and deepest water table depths occurred during the months of August to October, the end of the growing season, for all monitoring wells at all research sites (Figures 7-15). Wetland depressions are ponded 3 to 12 months per year. Wet prairies and sedge wetland zones are ponded 0 to 3 months. In general, mean and shallowest water table depths paralleled surface topography and mollic epipedon thickness on summits and backslopes at all research sites, reflecting the recharge and throughflow hydrologic nature of these areas (Figures 16-24). Mean and shallowest water table depths did not parallel the surface topography and mollic epipedon thickness in soils on wet prairie

Table 3. Vegetative zones along restored hillslopes in Colo Bog Complex.

Well	Current Vegetation	Landscape Position	Common Species
			Transect 1
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
6	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
7	Pond Depression	Footslope	*Carex typhina* (cattail sedge)
8	Pond Depression	Toeslope	*Carex typhina* (cattail sedge)
			Transect 2
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Wet Prairie	Footslope	*Aster simplex* (whitefield aster); *Panicum* species
6	Sedge Wetland Pond	Toeslope	*Dulichium arundinaceum* (three-way sedge)
			Transect 3
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Wet Prairie	Footslope	*Panicum* species (switchgrass); *Aster simplex* (whitefield aster); *Asclepsias* sp (milkweed)
5	Wetland Zone	Footslope	*Cyperus* sp. (Flatsedge); *Aster simplex* (whitefield aster); *Scirpus* sp (bulrush)
6	Cattail Wetland Pond	Toeslope	*Carex typhina* (cattail sedge)
7	Wet Prairie	Footslope	*Panicum* species; *Aster simplex* (whitefield aster); *Setaria* sp (foxtail).

Table 4. Vegetative zones along restored hillslopes in Harrier's Marsh.

Well	Current Vegetation	Landscape Position	Common Species
			Transect 1
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Wetland Zone	Footslope	*Phalaris arundinacea* (reed canarygrass) and *Carex Typhina* (cattail sedge)
5	Cattail Zone	Footslope	*Carex Typhina* (cattail sedge)
6	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
			Transect 2
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Wetland Zone	Footslope	*Phalaris arundinaceae* (reed canarygrass) and *Carex Typhina* (cattail sedge)
4	Cattail Zone	Footslope	*Carex Typhina* (cattail sedge)
5	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
6	Cattail Zone	Toeslope	*Carex Typhina* (cattail sedge)
7	Cattail Zone	Toeslope	*Carex Typhina* (cattail sedge)
			Transect 3
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Lower Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Three-way Sedge Zone	Footslope	*Dulichium arundinaceum* (three-way sedge)
6	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)

Table 5. Vegetative zones along restored hillslopes in Gordon's Marsh.

Well	Current Vegetative Use	Landscape Position	Common Species
			Transect 1
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Upper Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Lower Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Wet Prairie	Upper Footslope	*Phalaris arundinacea* (Reed Canary Grass); *Aster simplex* (Whitefield aster); *Panicum* species
6	Sedge Zone	Lower Footslope	*Dulichium arundinaceum* (Three-way sedge)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (Waterhemp); and *Setaria* species (Foxtail)
8	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (Waterhemp); and *Setaria* species (Foxtail)
			Transect 2
1	Upland Prairie	Shoulder	*Panicum* species (Switchgrass); *Andropogon* species (Bluestem)
2	Upland Prairie	Backslope	*Panicum* species (Switchgrass); *Andropogon* species (Bluestem)
3	Wet PrairieI	Upper Footslope	*Panicum* species; *Phalaris arundinaceae* (Reed Canarygrass); *Aster simplex* (whitefield aster)
4	Wet PrairieII	Middle Footslope	*Phalaris arundinacea* (Reed Canarygrass); *Panicum* species (switchgrass); *Carex typhina* (Cattail Sedge)
5	Cattail Zone	Lower Footslope	*Carex typhina* (Cattail sedge)
6	Pond Depression	Toeslope	*Eleocharis* species (Spikerush)
			Transect 3
1	Alfalfa Food Plot	Summit	*Medicago sativa*
2	Mowed Trail	Summit	Mowed trail
3	Oak/Cedar Forest	Backslope	*Quercus* species
4	Bromegrass Prairie	Upper Footslope	*Bromus inermis* (Smooth Bromegrass); *Phalaris arundinacea* (Reed Canarygrass)
5	RCG Pond Depression	Lower Footslope	*Phalaris arundinacea* (Reed Canarygrass)
6	RCG Pond Depression	Toeslope	*Phalaris arundinacea* (Reed Canarygrass)
7	RCG Pond Depression	Toeslope	*Phalaris arundinacea* (Reed Canarygrass)

Table 6. Soil series and classification along the restored hillslopes in Colo Bog.

Well	Soil Series	Classification	Natural Drainage[1]	Slope Element	Current Ecology
		Transect 1			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	Summit	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWP	Summit	Upland Prairie
3	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Backslope	Upland Prairie
4	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Backslope	Upland Prairie
5	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
6	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Pond Depression
8	Can.-Okoboji	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Very Poor	Toeslope	Pond Depression
		Transect 2			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWP	Shoulder	Upland Prairie
2	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
4	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	Toeslope	Sedge Depression
		Transect 3			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Shoulder	Upland Prairie
2	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
4	Delft-Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	Footslope	Wet Prairie I
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie II
6	Glencoe	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Very Poor	Toeslope	Cattail Depression
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie III

1 = SWP – somewhat poorly drained; MWD = moderately well drained

Table 7. Soil series and classification along the restored hillslopes in Harrier's Marsh.

Well	Soil Series	Classification	Natural Drainage	Slope Element	Current Ecology
		Transect 1			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD[1]	ST[2]	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	SH	Upland Prairie
3	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wetland Zone
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
6	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	TS	Pond Depression
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 2			
1	Crippin	Fine-loamy, mixed, superactive, calcareous, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
2	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
3	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wetland Zone
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
5	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
6	Harps	Fine-loamy, mixed, superactive, mesic Typic Calciaquoll	Poor	TS	Cattail Zone
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	TS	Cattail Zone
		Transect 3			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	ST	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	SH	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Sedge Zone
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression

1 = SWP – somewhat poorly drained; MWD = moderately well drained
2 = ST = summit; SH = shoulder; BS = backslope; FS = footslope; TS = toeslope

Table 8. Soil series and classification along the restored hillslopes in Gordon's Marsh.

Well	Soil Series	Classification	Natural Drainage	Slope Element	Current Ecology
		Transect 1			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP[1]	St[2]	Upland Prairie[3]
2	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
3	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	BS	Upland Prairie
5	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	FS	Wet Prairie
6	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	FS	Sedge Zone
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very poor	TS	Pond Depression
8	Wacousta	Fine-silty, mixed, mesic Typic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 2			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
2	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
3	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wet Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wet Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 3			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	St	Alfalfa food plot
2	Delft T	Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll	Poor	St	Mowed trail
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	BS	Oak/cedar forest
4	Canisteo	Fine-loamy, mixed, superactive, calcareous Typic Endoaquoll	Poor	FS	Bromegrass Zone
5	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	FS	RCG Depression
6	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	TS	RCG Depression
7	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	TS	RCG Depression

T = Taxadjunct.
1 = SWP – somewhat poorly drained.
2 = St – summit; SH – shoulder; BS = Backslope; FS = Footslope; TS = Toeslope.
3 = RCG = Reed Canary Grass.

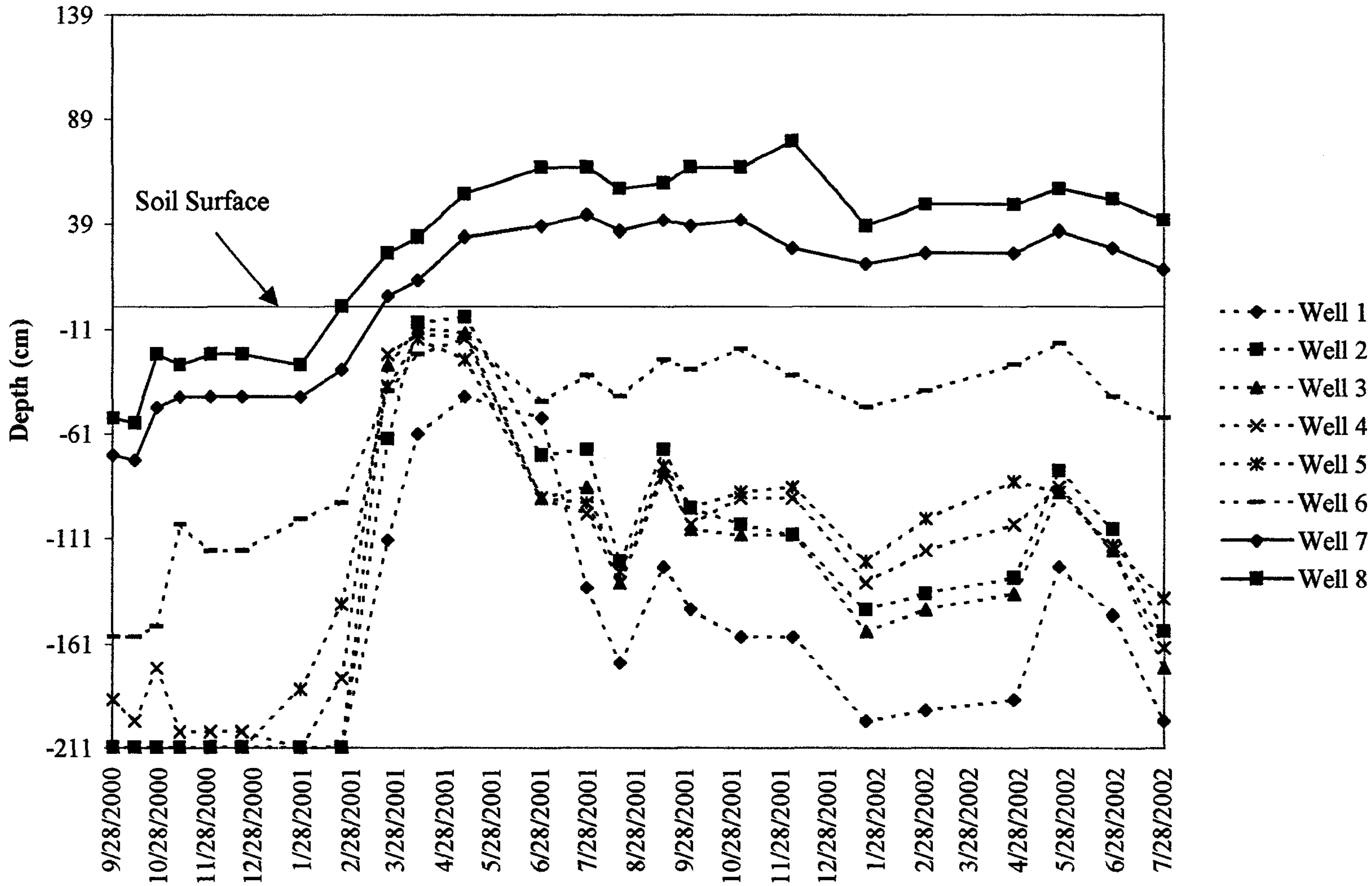

Figure 7. Monthly water table fluctuations along transect 1 in Colo Bog.

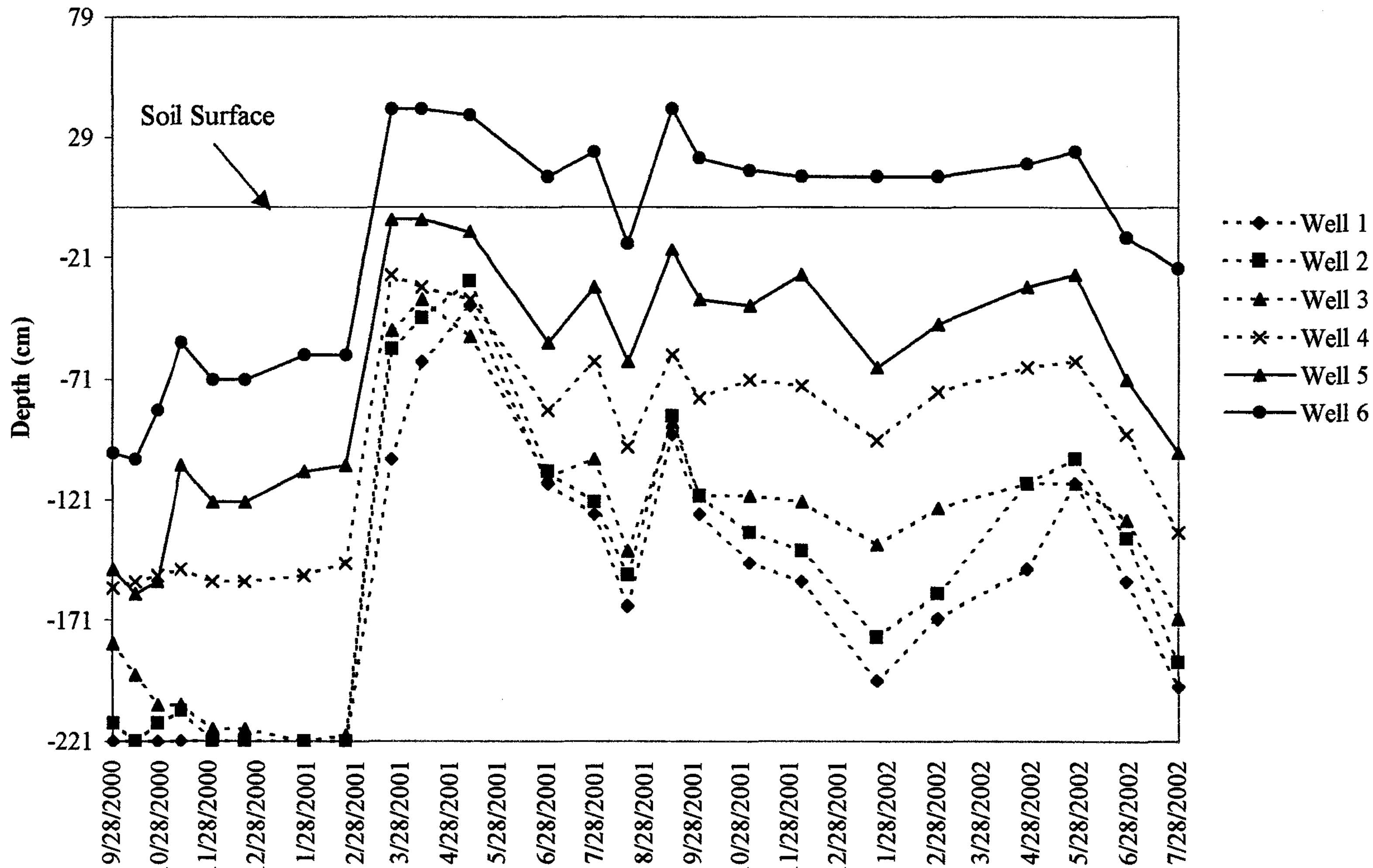

Figure 8. Monthly water table fluctuations along transect 2 in Colo Bog.

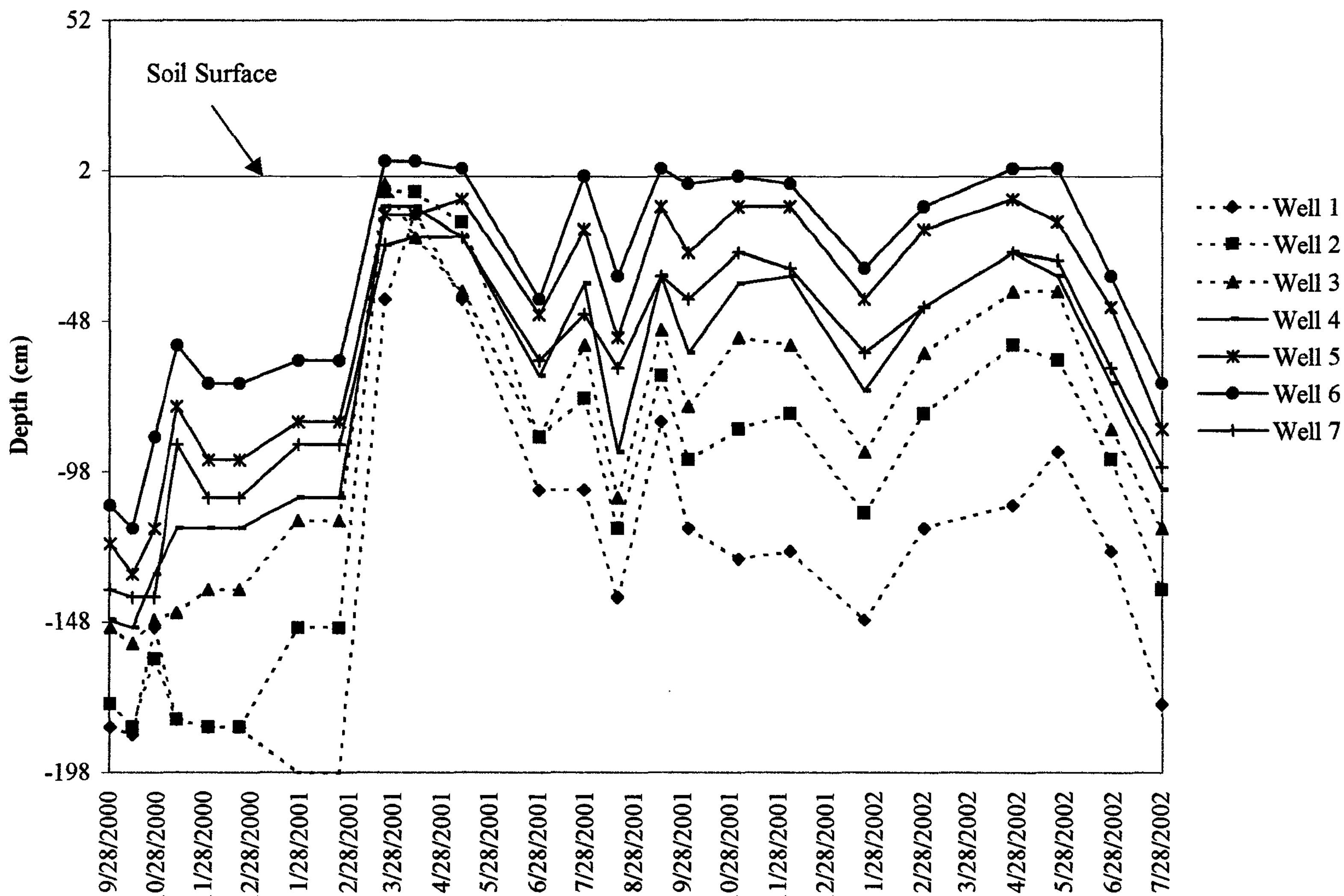

Figure 9. Monthly water table fluctuations along transect 3 in Colo Bog.

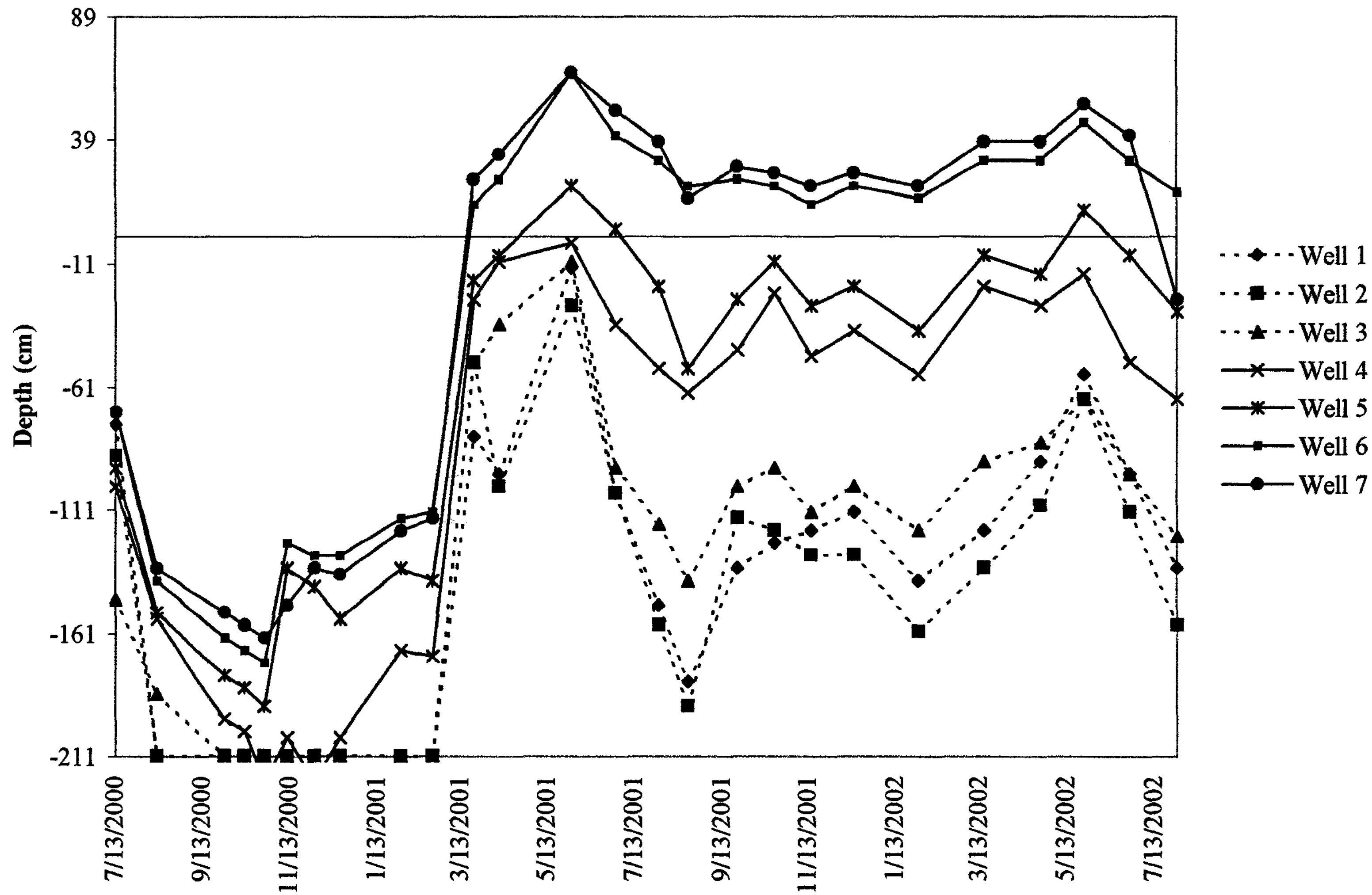

Figure 10. Monthly water table fluctuations along transect 1 in Harrier's Marsh.

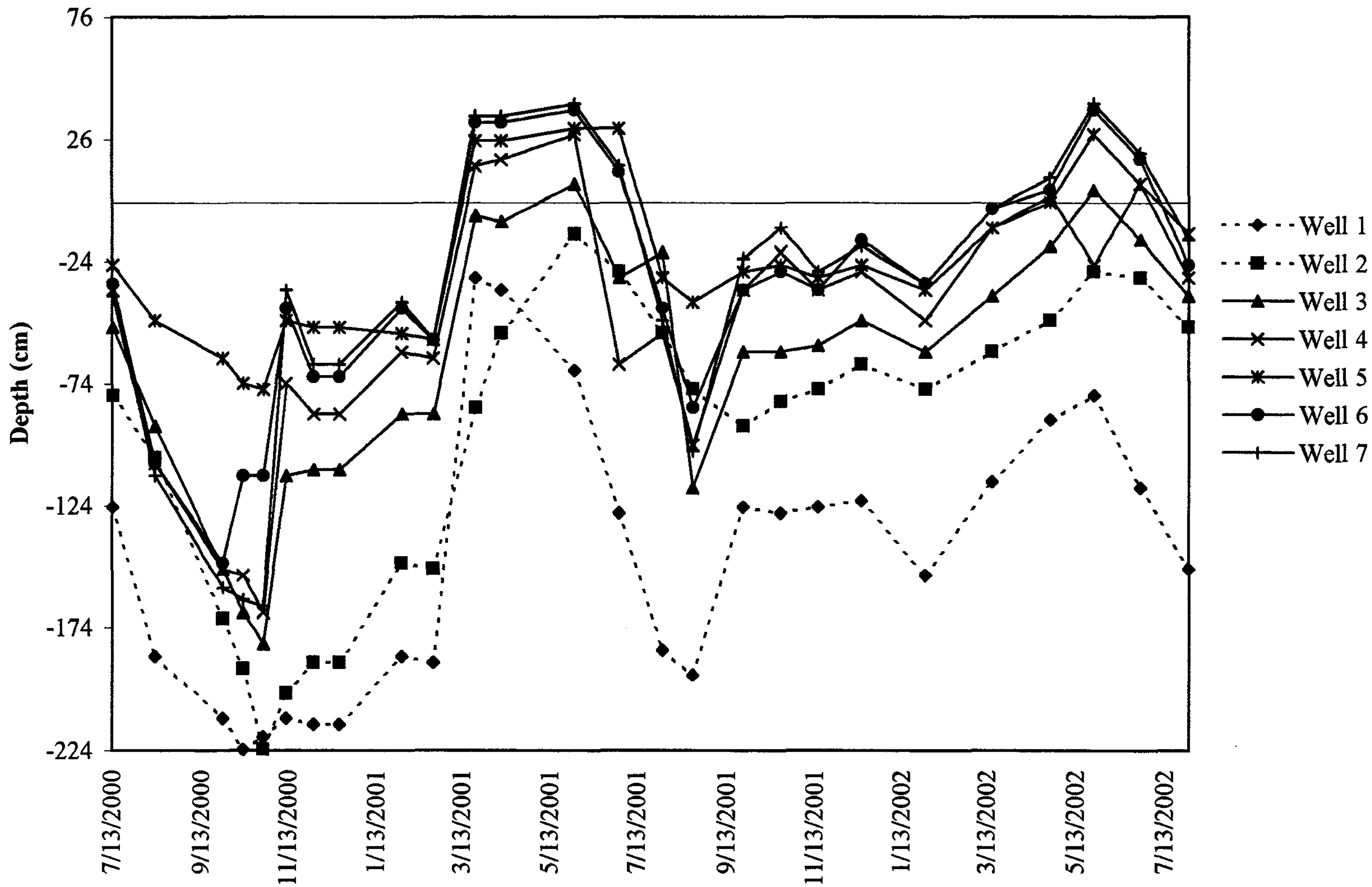

Figure 11. Monthly water table fluctuations along transect 2 in Harrier's Marsh.

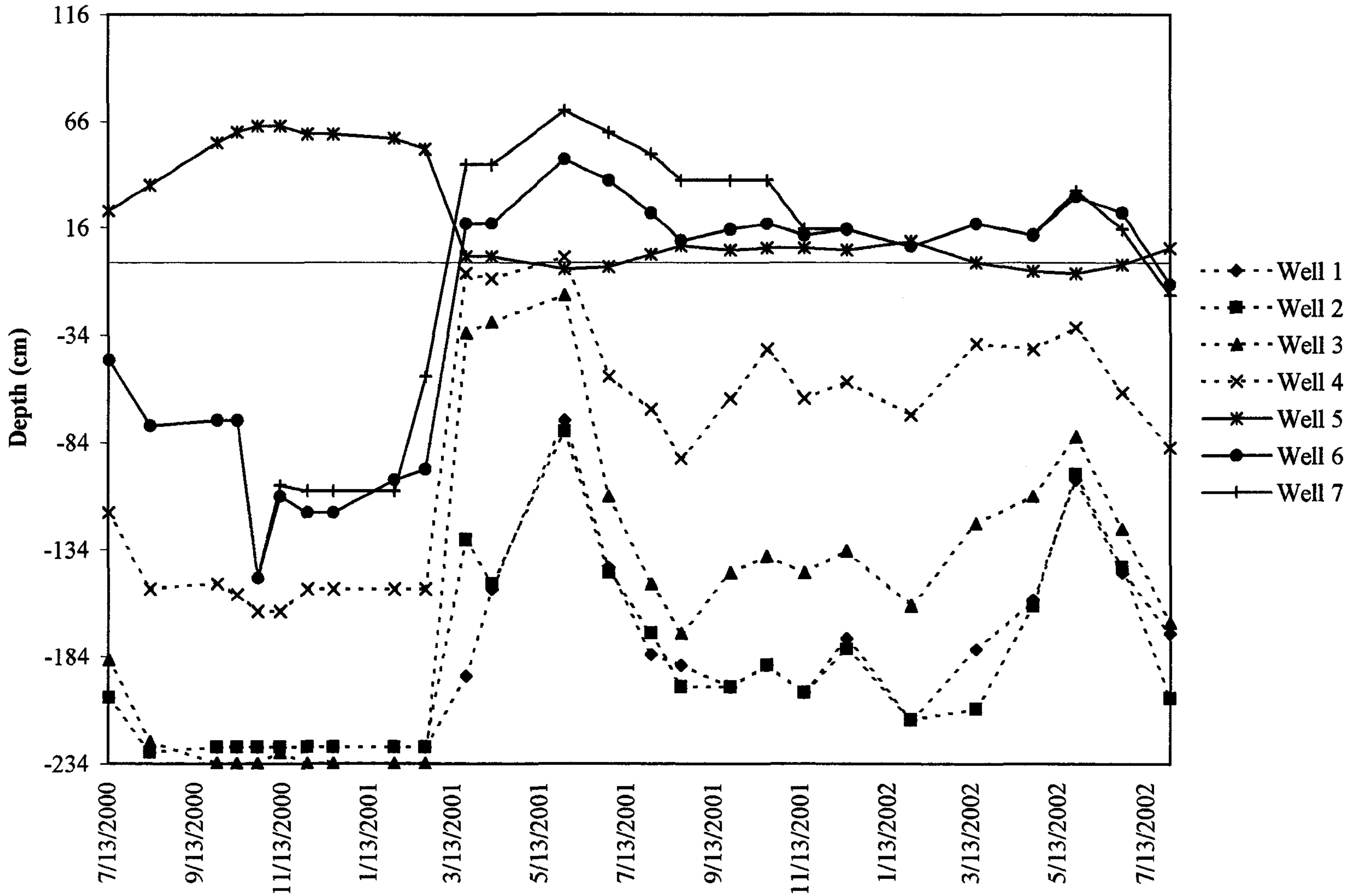

Figure 12. Monthly water table fluctuations along transect 3 in Harrier's Marsh.

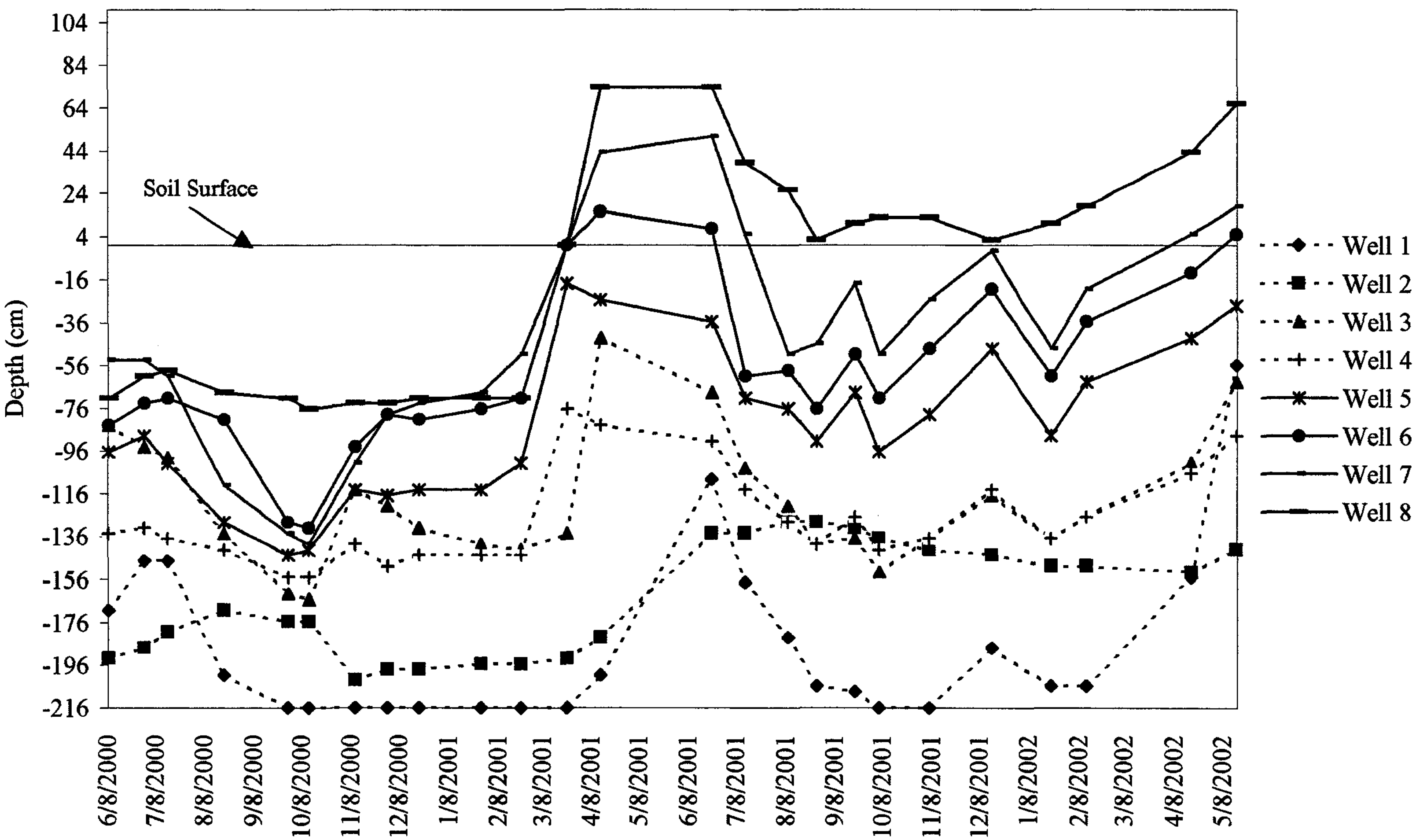

Figure 13. Monthly water table fluctuations along transect 1 in Gordon's Marsh.

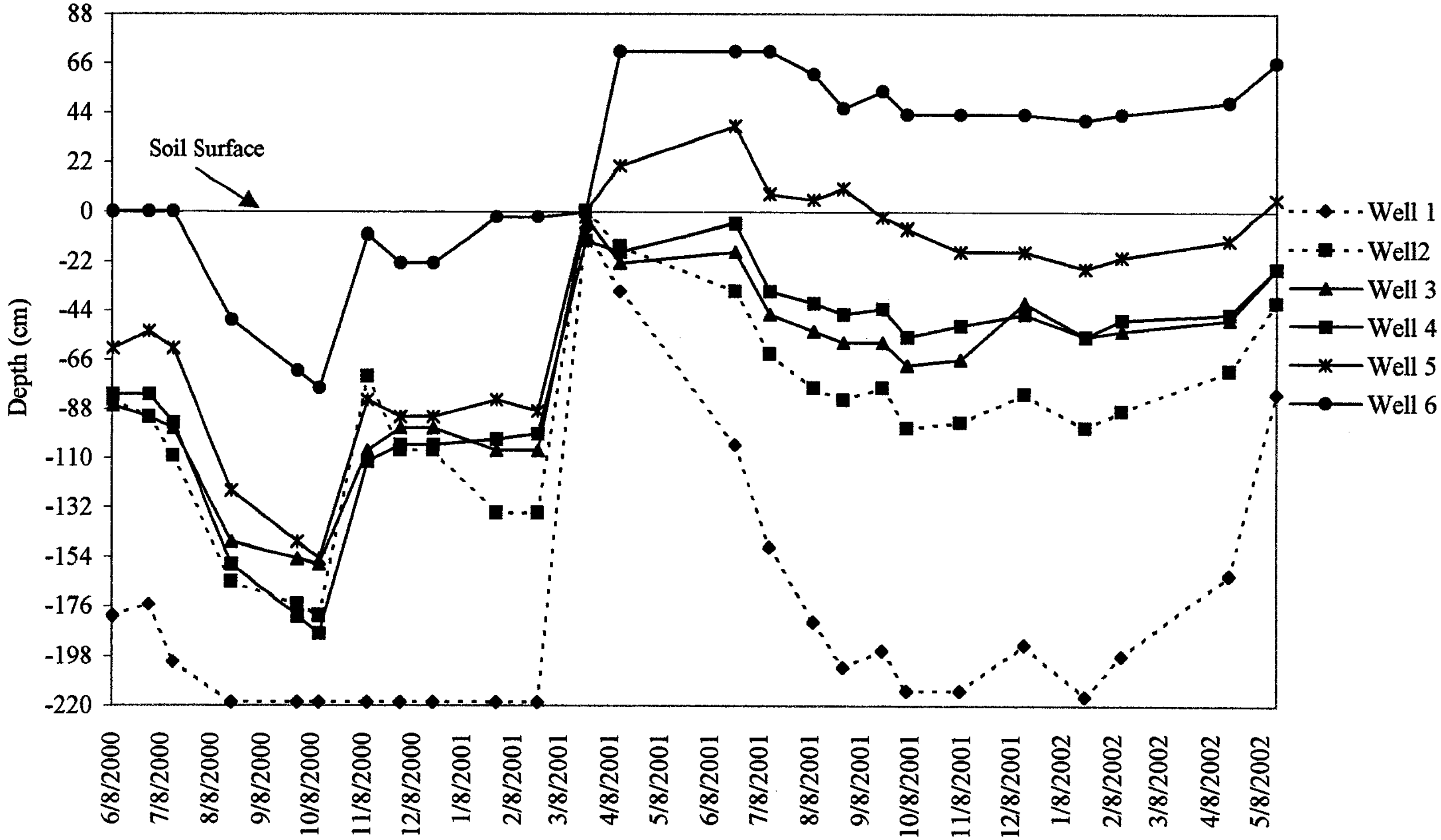

Figure 14. Monthly water table fluctuations along transect 2 in Gordon's Marsh.

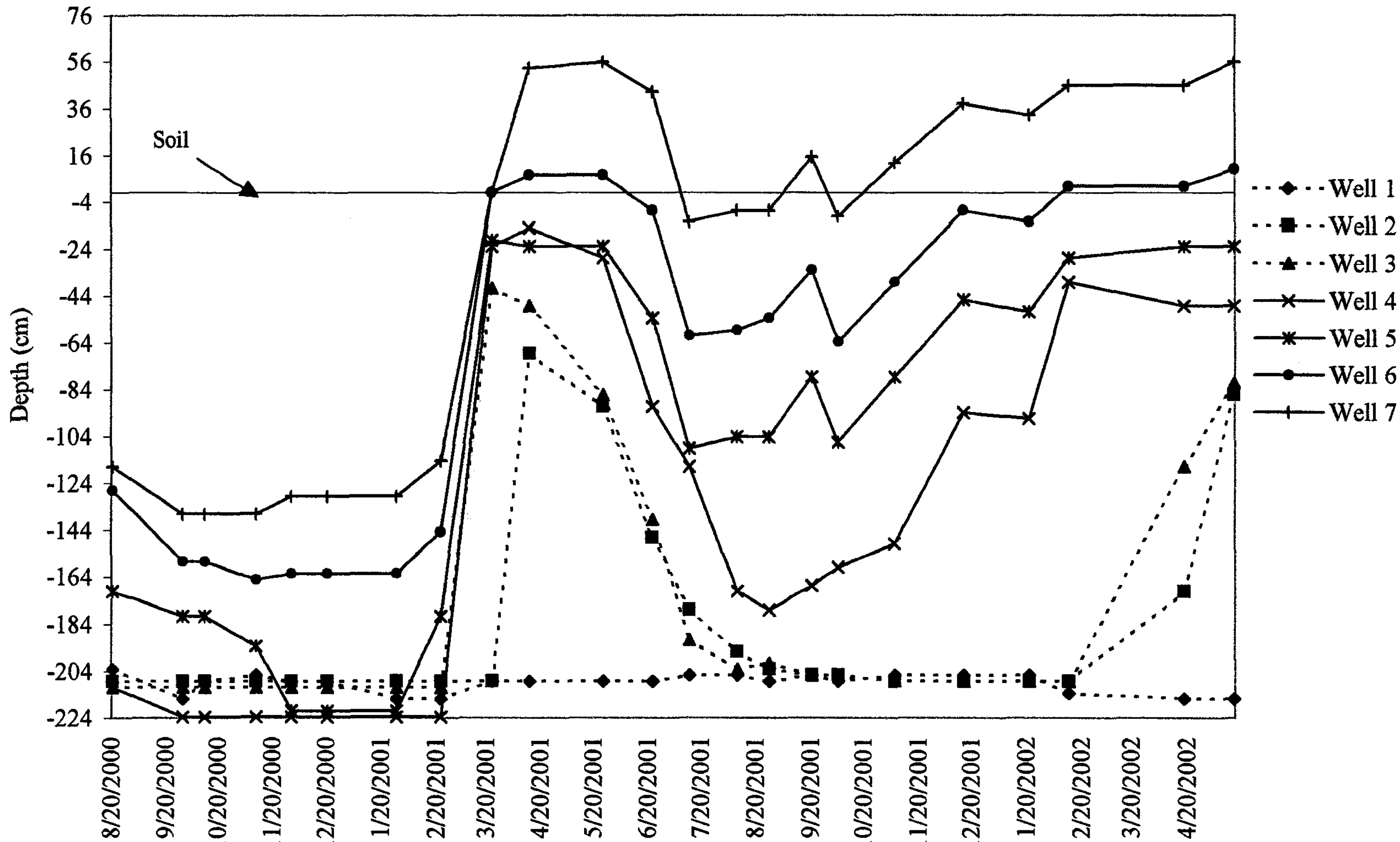

Figure 15. Monthly water table fluctuations along transect 3 in Gordon's Marsh.

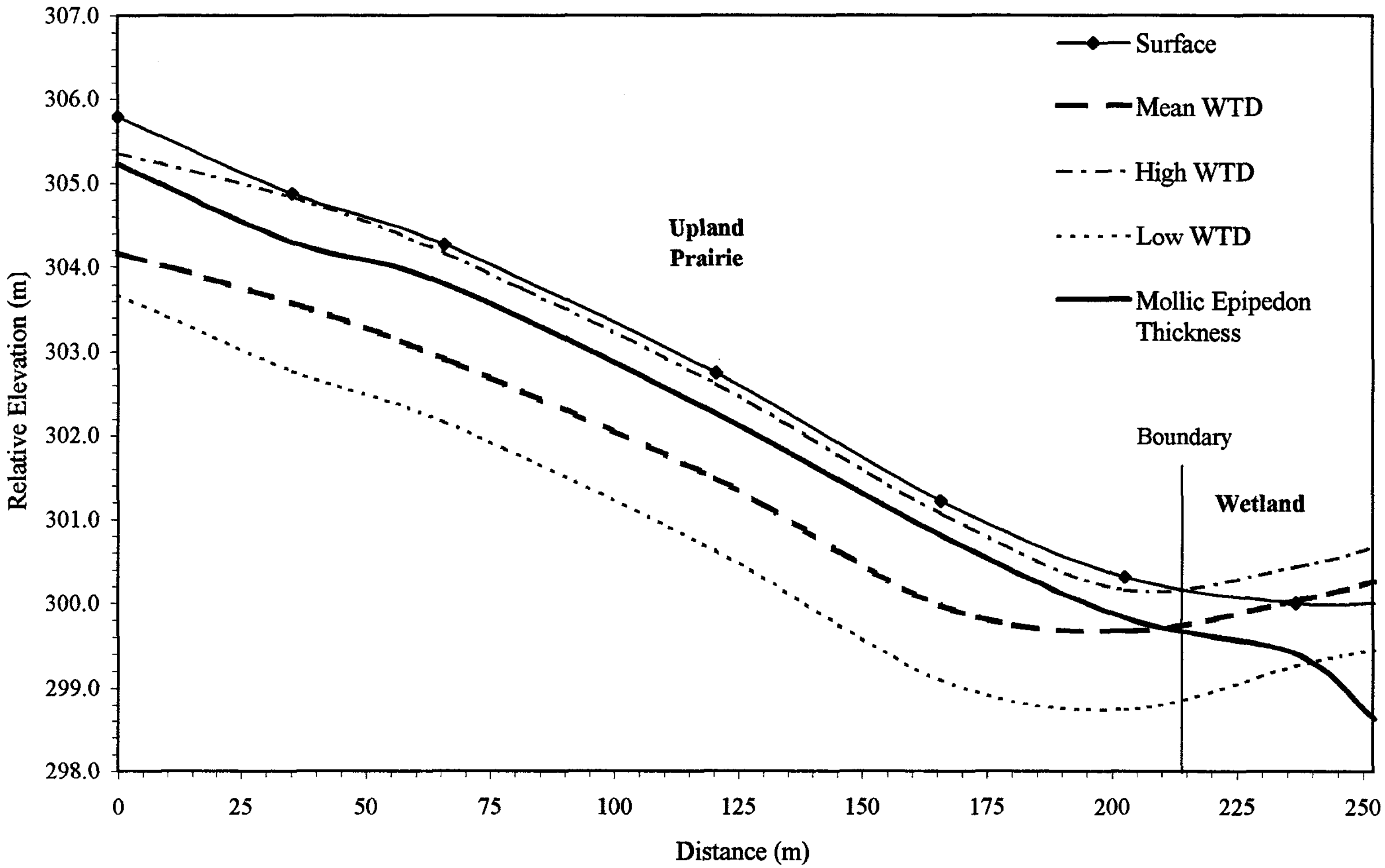

Figure 16. Water table fluctuations along transect 1 in Colo Bog.

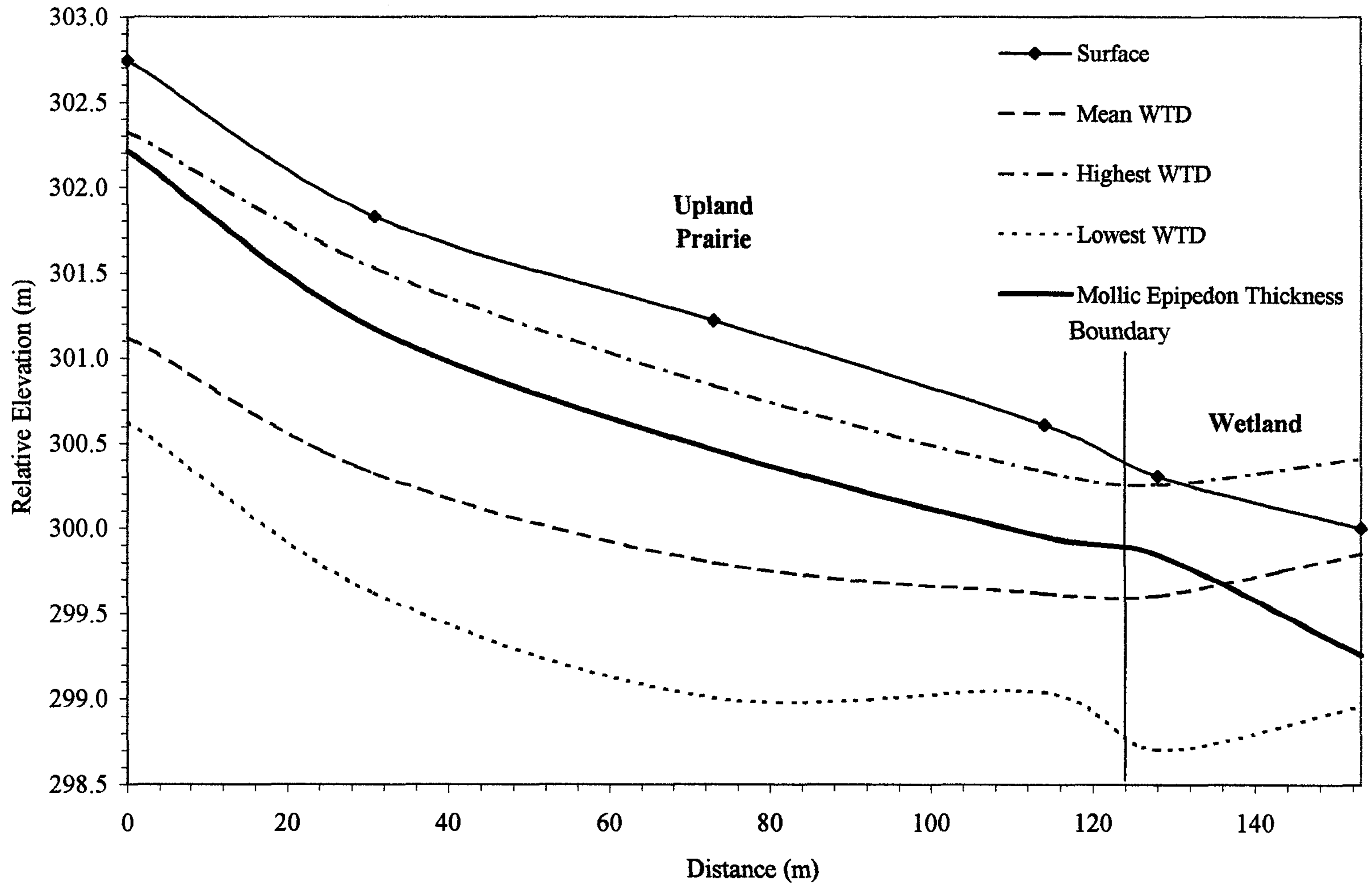

Figure 17. Water table fluctuations along transect 2 in Colo Bog.

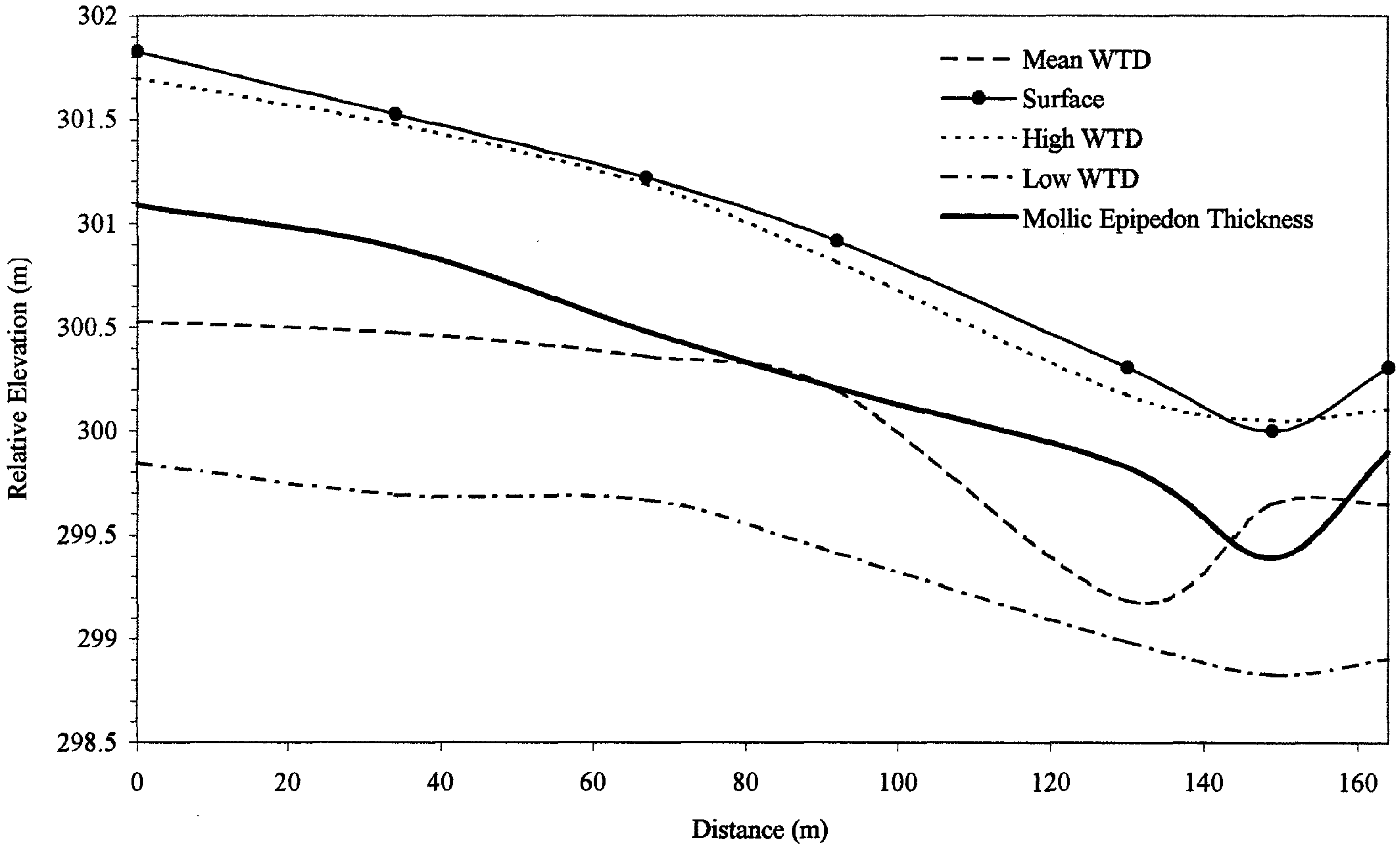

Figure 18. Water table fluctuations along transect 3 Colo Bog.

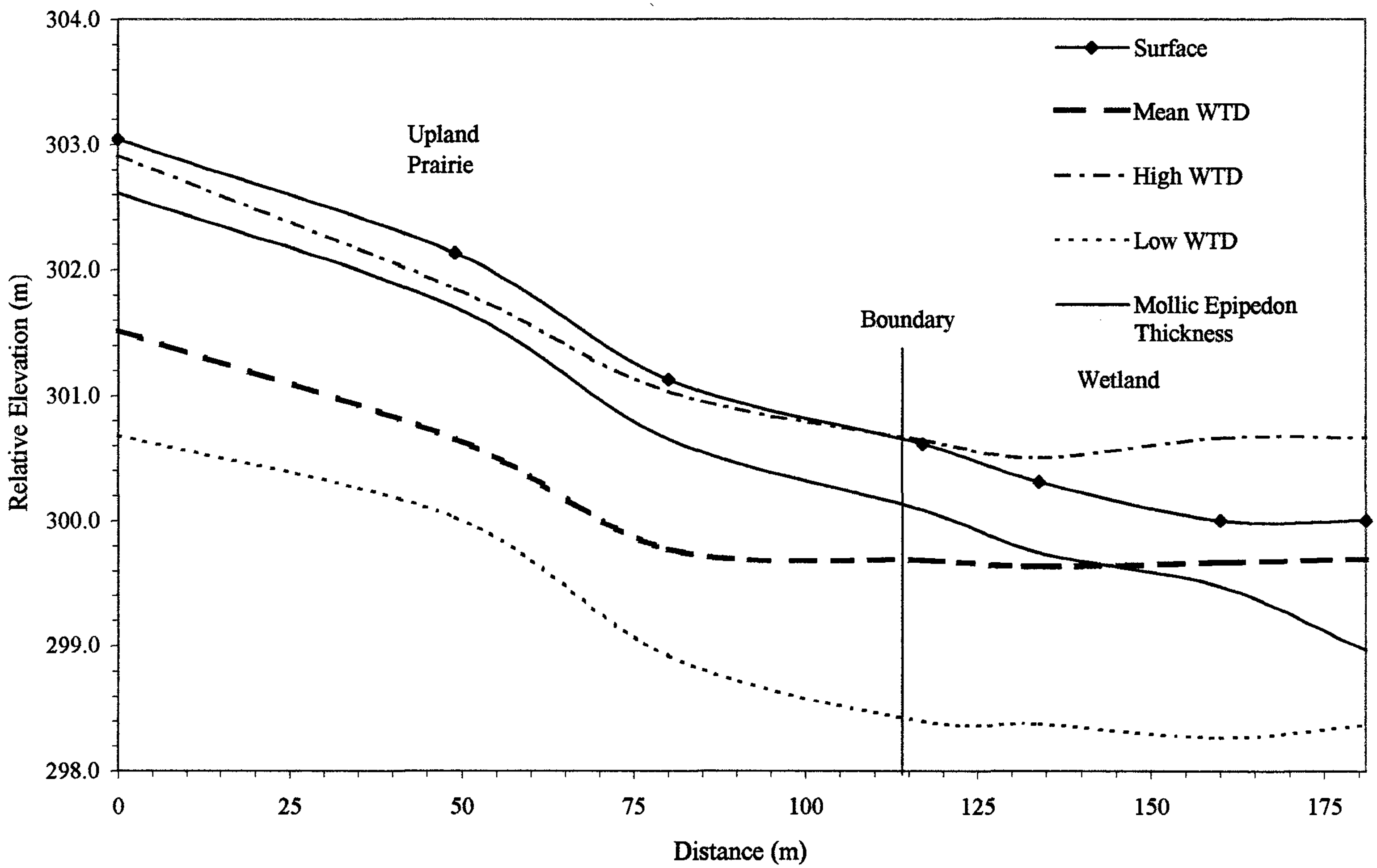

Figure 19. Water table fluctuations along transect 1 in Harrier's Marsh.

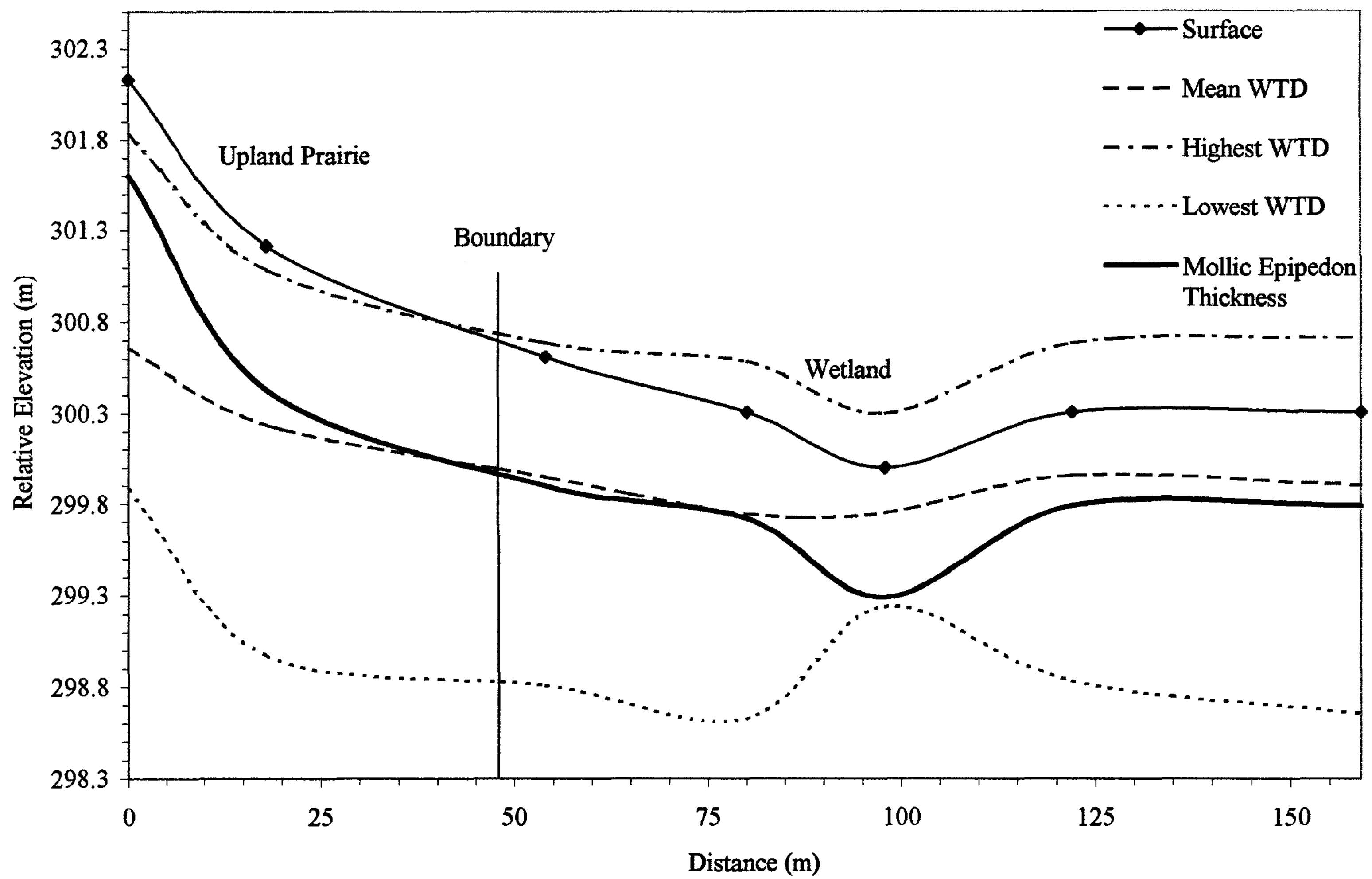

Figure 20. Water table fluctuations along transect 2 in Harrier's Marsh.

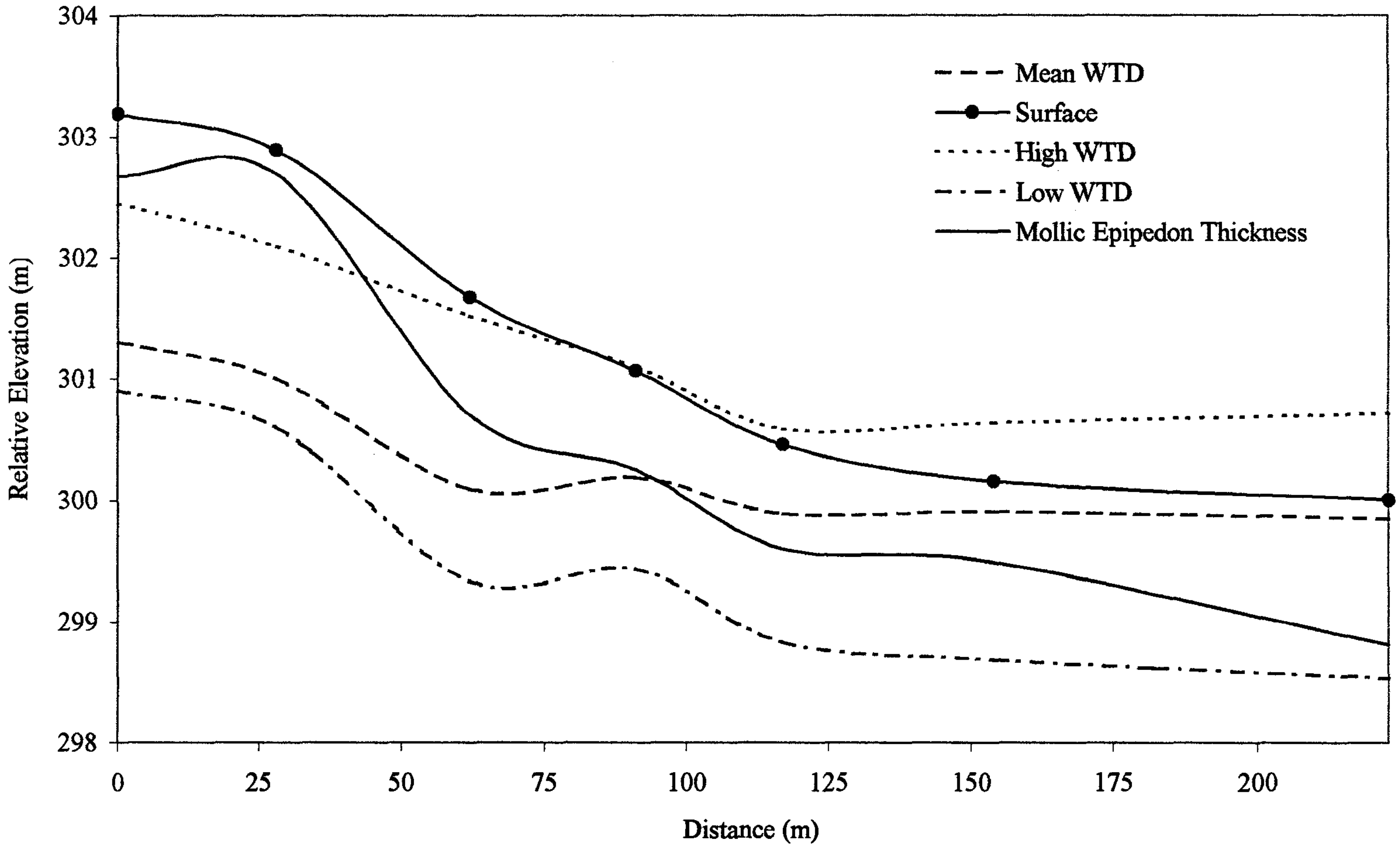

Figure 21. Water table fluctuations along transect 3 in Harrier's Marsh.

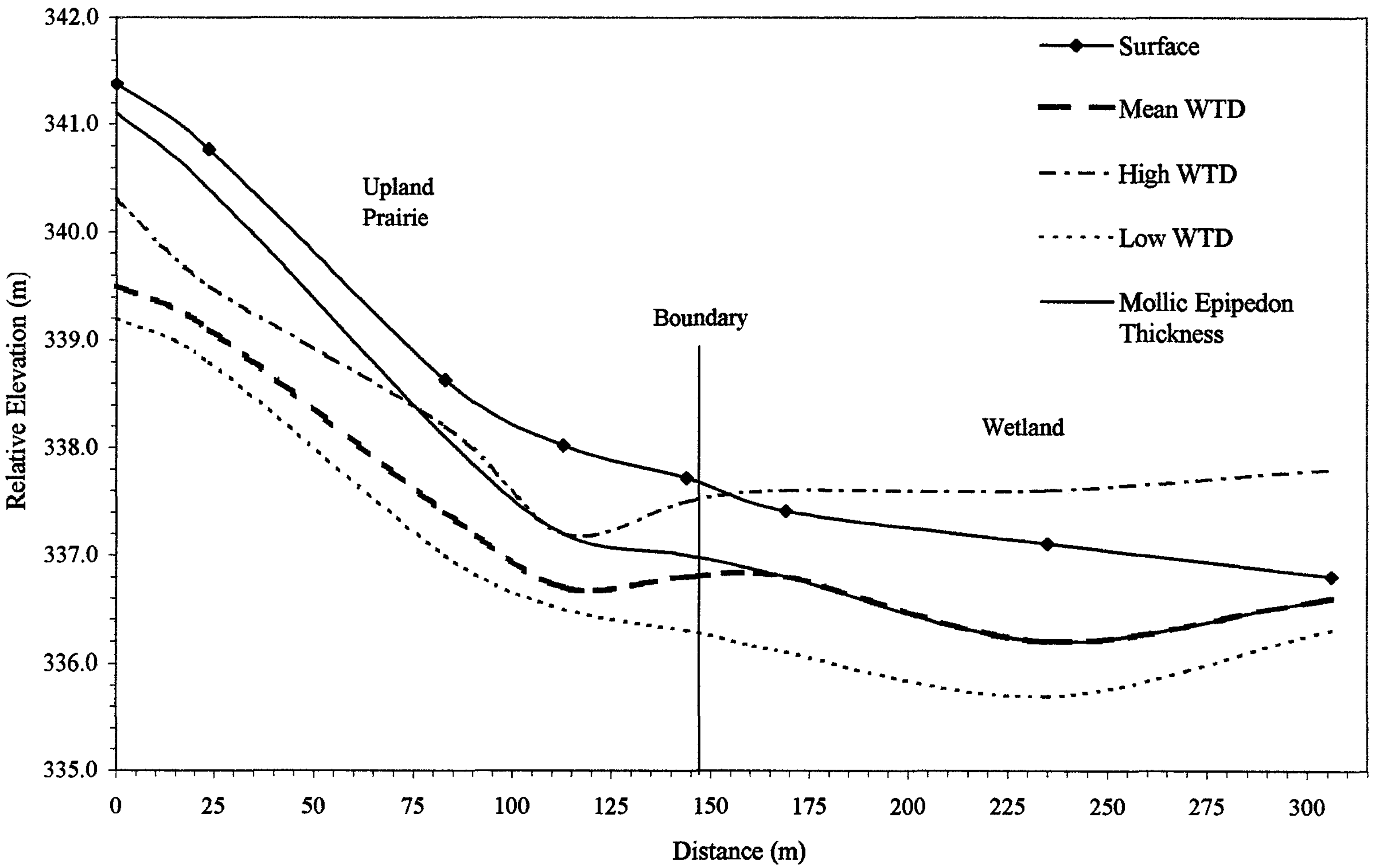

Figure 22. Water table fluctuations along transect 1 in Gordon's Marsh.

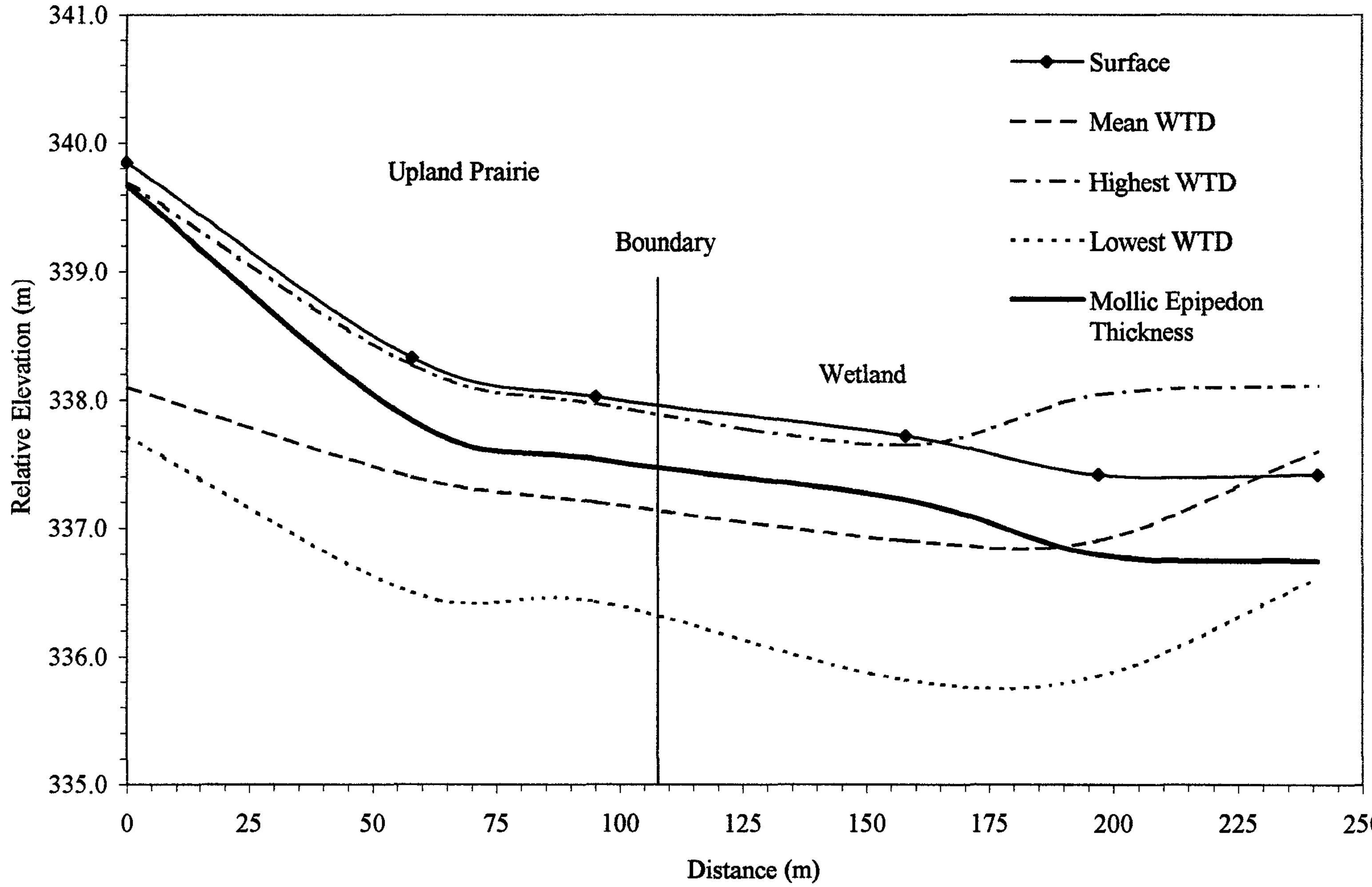

Figure 23. Water table fluctuations along transect 2 in Gordon's Marsh.

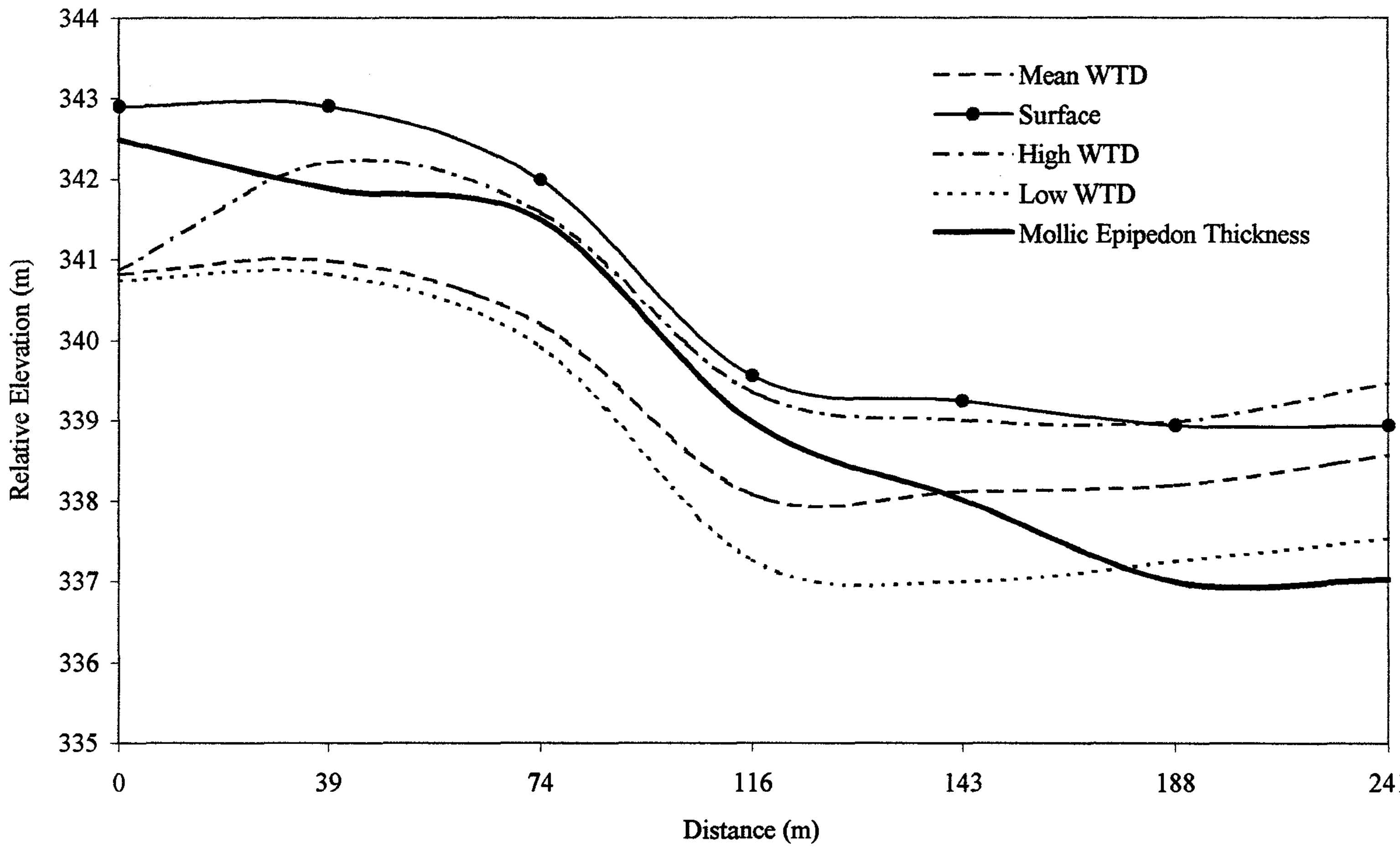

Figure 24. Water table fluctuations along transect 3 in Gordon's Marsh.

and sedge wetland zones and pond depressions. A depression in mean soil water table depth typically occurred at the rim of the pond depressions, commonly wet prairie and sedge zones, in the majority of the transects. The depression in mean water table depth may reflect the occurrence of more phreatophytes or hydrophytes in these zones than in adjacent upland sites. These plants are consumptive water users and can act like a water pump and influence the local hydrology (Richardson et al., 2001). Mean and shallowest water table depths converge upward on the toeslopes, reflecting the discharge nature. These figures also illustrate the inverse relationship between water table depths and mollic epipedon thickness. Khan and Fenton (1994) reported that soils on higher landscape positions have greater fluctuations in water table levels in comparison to soils on lower landscape positions. However, this relationship was observed for a drained hydrosequence. Reuter and Bell (2001) observed that the largest fluctuation in water table levels occurred on the lower and upper footslope positions on a wetland-upland hillslope, on a sandy glacial outwash plain, in east-central Minnesota. This study agrees with the findings of Khan and Fenton (1994).

Soil Hydromorphology of Group I soils.

Mean annual water table depths ranged from 130 to 162 cm below the soil surface in Colo Bog (Table 9). Shallowest annual water table depths ranged from 5 to 43 cm below the soil surface in Colo Bog. Mean annual water table depths ranged from 147 to 189 cm below the soil surface in Harrier's Marsh (Table 10). Shallowest annual water table depths ranged from 13 to 79 cm below the soil surface. Mean annual water table depths ranged from 164 to 184 cm below the soil surface in Gordon's Marsh (Table 11). Shallowest annual water table depths ranged from 19 to 130 cm below the soil surface. In general, Clarion soils had shallowest annual water table depths around 40 cm below the soil surface, whereas Nicollet soils had shallowest annual water table depths above 20 cm in the profile. The calcareous Crippin soil on transect 2 in Harrier's Marsh had water table statistics similar to Nicollet soils. In contrast, mean water table depth was 209 cm in the alfalfa plot in transect

Table 9. Descriptive water table statistics for hillslopes in Colo Bog.

Well	Current Ecology	Slope Element	Soil Series	Mean[1] cm	High cm	Low cm
			Transect 1			
1	Upland Prairie	Summit	Clarion	-162	-43	-211
2	Upland Prairie	Summit	Clarion	-131	-5	-211
3	Upland Prairie	Backslope	Nicollet	-136	-10	-211
4	Upland Prairie	Backslope	Nicollet	-126	-13	-213
5	Upland Prairie	Backslope	Webster	-124	-15	-213
6	Upland Prairie	Backslope	Webster	-64	-15	-157
7	Cattail Pond Depression	Footslope	Canisteo	+3	+43	-74
8	Cattail Pond Depression	Toeslope	Canisteo-Okoboji	+26	+66	-56
			Transect 2			
1	Upland Prairie	Shoulder	Clarion	-162	-41	-221
2	Upland Prairie	Backslope	Delft	-151	-30	-221
3	Upland Prairie	Backslope	Delft	-142	-38	-221
4	Upland Prairie	Backslope	Delft	-99	-28	-157
5	Wet Prairie	Footslope	Canisteo	-70	-5	-160
6	Sedge Pond Depression	Toeslope	Okoboji	-15	+41	-104
			Transect 3			
1	Upland Prairie	Shoulder	Nicollet	-130	-13	-198
2	Upland Prairie	Backslope	Webster	-105	-5	-183
3	Upland Prairie	Backslope	Delft	-86	-3	-155
4	Wet Prairie I	Footslope	Delft-Canisteo	-72	-10	-150
5	Wet Prairie II	Footslope	Canisteo	-51	-13	-132
6	Cattail Pond Depression	Toeslope	Glencoe	-35	+5	-117
7	Wet Prairie III	Footslope	Canisteo	-66	-20	-140

1 = - level below soil surface; + level above soil surface.

Table 10. Descriptive water table statistics for hillslopes in Harrier's Marsh.

Well	Current Ecology	Slope Element	Soil Series	Mean[1] cm	High cm	Low cm
			Transect 1			
1	Upland Prairie	Summit	Clarion	-152	-13	-236
2	Upland Prairie	Shoulder	Clarion	-148	-28	-211
3	Upland Prairie	Backslope	Webster	-136	-10	-221
4	Wetland Zone	Footslope	Canisteo	-93	+3	-221
5	Cattail Zone	Footslope	Canisteo	-67	+20	-192
6	Pond Depression	Toeslope	Canisteo	-34	+66	-173
7	Pond Depression	Toeslope	Okoboji	-31	+66	-163
			Transect 2			
1	Upland Prairie	Shoulder	Crippin	-147	-30	-224
2	Upland Prairie	Backslope	Canisteo	-98	-13	-224
3	Wetland Zone	Footslope	Canisteo	-66	+8	-180
4	Cattail Zone	Footslope	Canisteo	-56	+28	-168
5	Pond Depression	Toeslope	Okoboji	-25	+30	-76
6	Cattail Zone	Toeslope	Harps	-35	+38	-147
7	Cattail Zone	Toeslope	Canisteo	-40	+41	-165
			Transect 3			
1	Upland Prairie	Summit	Clarion	-189	-74	-229
2	Upland Prairie	Shoulder	Clarion	-189	-79	-229
3	Upland Prairie	Backslope	Delft	-158	-15	-234
4	Upland Prairie	Backslope	Canisteo	-88	+3	-163
5	Sedge Zone	Footslope	Canisteo	-57	+13	-163
6	Pond Depression	Toeslope	Okoboji	-25	+48	-147
7	Pond Depression	Toeslope	Okoboji	-16	+71	-147

1 = - level below soil surface; + level above soil surface.

Table 11. Descriptive water table statistics for hillslopes in Gordon's Marsh.

Well	Current Ecology[1]	Slope Element[2]	Soil Series[3]	Mean[4] cm	High cm	Low cm
			Transect 1			
1	Upland Prairie	Summit	Nicollet	-184	-56	-216
2	Upland Prairie	Shoulder	Nicollet	-164	-130	-203
3	Upland Prairie	Upper BS	Webster	-118	-43	-165
4	Upland Prairie	Lower BS	Delft T	-127	-76	-155
5	Wet Prairie	Upper FS	Delft T	-82	-18	-145
6	Sedge Zone	Lower FS	Delft T	-56	+15	-132
7	Pond Depression	Toeslope	Okoboji	-41	+51	-140
8	Pond Depression	Toeslope	Wacousta	-13	+74	-76
			Transect 2			
1	Upland Prairie	Shoulder	Nicollet	-176	-19	-218
2	Upland Prairie	Backslope	Webster	-90	-3	-180
3	Wet Prairie	Upper FS	Canisteo	-73	-3	-157
4	Wet Prairie	Middle FS	Canisteo	-72	-5	-188
5	Cattail Zone	Lower FS	Canisteo	-40	+38	-155
6	Pond Depression	Toeslope	Okoboji	+20	+71	-79
			Transect 3			
1	Alfalfa Food Plot	Summit	Nicollet	-209	-203	-216
2	Mowed Trail	Summit	Delft T	-185	-69	-208
3	Oak/Cedar Forest	Backslope	Delft	-174	-41	-211
4	Bromegrass Prairie	Upper FS	Canisteo	-135	-15	-224
5	RCG Pond Depression	Lower FS	Klossner	-103	-20	-221
6	RCG Pond Depression	Toeslope	Klossner	-65	+10	-165
7	RCG Pond Depression	Toeslope	Klossner	-26	+56	-137

1 = RCG - Reed Canary Grass.
2 = FS - Footslope.
3 = T – Taxadjuncts.
4 = - level below soil surface; + level above soil surface.

3 of Gordon's Marsh. Shallowest water table depth for this drained alfalfa site was 203 cm below the soil surface. The adjacent drainage ditch influenced the water table dynamics of these soils.

The presence of the water table in the soil profile varied among soils on each hillslopes. The water table was observed 0 to 4% of the time from 0-25 cm, 4 to 13% from 25-50 cm, 8 to 19% from 50-75 cm, 13 to 23% from 75-100 cm, 25 to 42% from 100-125 cm, 38 to 63% from 125-150 cm, 58 to 67% from 150-175 cm, and 67 to 100% from 175-200 cm in Colo Bog (Table 12). The water table was observed 0 to 2% of the time from 0-25 cm, 0 to 8% from 25-50 cm, 2 to 12% from 50-75 cm, 6-22% from 75-100 cm, 8 to 40% from 100-125 cm, 18 to 54% from 125-150 cm, 29 to 62% from 150-175 cm, and 44 to 77% from 175-200 cm in Harrier's Marsh (Table 13). The water table was observed 0 to 4% of the time from 0-25 cm, 0 to 8% from 25-50 cm, 2 to 8% from 50-100 cm, 3 to 13% from 100-125 cm, 13 to 24% from 125-150 cm, 21 to 39% from 150-175 cm, and 46 to 66% from 175-200 cm in Gordon's Marsh (Table 14). The water table was never observed in the cultivated summit soil on transect in Gordon's Marsh.

Four pedons were assigned to Group I soils in Colo Bog. Two of the pedons were within the range of the Clarion series, whereas the other two classified as Nicollet. Depth to redoximorphic features ranged from 53 to 109 cm for Group I soils in Colo Bog (Tables 15, 18, and 22). Depth at which redoximorphic features occurred were saturated approximately 8 to 33% of the time. Free carbonates were absent in the solum or present below 81 cm. Thickness of the mollic epipedons ranged from 53 to 64 cm. The mollic epipedons were commonly loam to clay loam in textures, had moist color values of 2 and 3, moist chroma of 1, and pH values ranging from 5.4 to 6.4. Soils on summits commonly had cambic horizons (Bw) thinning on backslopes. Thickness of the cambic horizons ranged from 36 to 53 cm. The Bw horizons had pH values ranging from 6.1 to 6.8, moist values ranging from 2 to 5, and moist chromas ranging from 2 to 4. Nicollet soils had Bg horizons in the lower sola. These soils are somewhat poorly drained. The Clarion pedons lacked Bg horizons and these soils are moderately well-drained. The thickness of the Bg horizon ranged from 17 to 21

Table 12. Percent of time water table was present by depth along the restored hillslopes in Colo Bog.

Soil Group	% Time Saturated							
	0-25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm	150-175 cm	175-200 cm
				Transect 1				
I	4	6	19	23	34	48	59	67
II	11	26	27	88	44	69	77	81
III	-	-	-	-	-	-	-	-
IV	75	92	100	100	100	100	100	100
				Transect 2				
I	0	4	8	13	25	38	58	67
II	0	8	21	24	49	61	75	81
III	17	46	63	63	88	88	100	100
IV	63	63	88	92	100	100	100	100
				Transect 3				
I	4	13	13	21	42	63	67	100
II	11	17	36	59	69	80	90	100
III	23	49	61	77	91	99	100	100
IV	46	63	88	92	100	100	100	100

Table 13. Percent of time water table was present by depth along the restored hillslopes in Harrier's Marsh.

Soil Group	% Time Saturated							
	0-25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm	150-175 cm	175-200 cm
				Transect 1				
I	2	4	10	22	40	54	62	65
II	4	8	16	35	58	65	65	69
III	31	50	62	64	65	73	83	91
IV	62	62	65	65	73	87	100	100
				Transect 2				
I	0	8	12	19	31	50	58	77
II	4	19	38	65	69	73	81	92
III	34	59	74	81	90	91	99	100
IV	35	73	96	100	100	100	100	100
				Transect 3				
I	0	0	2	6	8	18	29	44
II	8	20	33	39	46	56	81	83
III	58	62	65	69	69	81	100	100
IV	62	67	75	81	96	100	100	100

Table 14. Percent of time water table was present by depth along the restored hillslopes in Gordon's Marsh.

Soil Group	% Time Saturated 0-25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm	150-175 cm	175-200 cm
				Transect 1				
I	0	0	2	2	3	24	39	66
II	0	2	4	17	36	88	100	100
III	13	25	48	78	90	100	100	100
IV	44	50	88	92	96	100	100	100
				Transect 2				
I	4	8	8	8	13	13	21	46
II	8	13	25	67	79	92	92	100
III	25	40	58	78	88	92	97	100
IV	88	92	100	100	100	100	100	100
				Transect 3 (Ditch Drained)				
I	0	0	0	0	0	0	0	0
II	0	5	7	12	14	19	21	27
III	9	23	23	36	41	41	59	59
IV	39	45	55	58	67	77	89	95

cm in the Nicollet soils. The Bg horizons had a moist value of 4, moist chroma of 2, and pH values ranging from 5.7 to 7.9. Cumulative thickness of horizons containing > 10 g kg^{-1} organic matter ranged from 64 to 74 cm.

Five pedons were assigned to Group I soils in Harrier Marsh. Four pedons were within the range of the Clarion series and one classified as Crippin. The depth to redoximorphic features ranged from 10 to 91 cm in Harrier's Marsh (Tables 26, 30, and 34). Depths at which redoximorphic features occurred in the sola were saturated 0 to 27% of the time. The Crippin soil on transect 2 had yellowish brown (10YR 5/4) mottles up to 10 cm. The upper 25 cm of the soil profile were never saturated, suggesting these mottles are relict features. Depth to free carbonates ranged from 53 to 150 cm. The thickness of the mollic epipedons ranged from 36 to 53 cm. The mollic epipedons commonly had loam textures, moist color values of 2 to 3, moist chromas of 1 to 3, and soil pH values of 5.1 to 7.5. The high pH values were in the Crippin soil. These soils formed in calcareous loam to clay loam till. The thickness of the cambic horizons, when present in the solum, ranged from 9 to 38 cm. These horizons had moist values of 3 to 4, moist chromas of 3 to 4, and soil pH values ranging from 5.9 to 7.4. The majority of the soils in the group were Clarion soils, except for the Crippin soil in transect 2. This soil had a Bg horizon that was 26 cm thick with chroma <2. The cumulative thickness of horizons with >10 g kg^{-1} organic matter ranged from 36 to 74 cm.

Three pedons were assigned to group I soils in Gordon's Marsh and were within the range of the Nicollet series. Depth to redoximorphic features ranged from 61 to 76 cm in Gordon's Marsh (Tables 38 and 42). Depths at which redoximorphic features occurred were saturated 0 to 8% of the time. Depth to carbonates ranged from 79 to 107 cm. The thickness of the mollic epipedons ranged from 28 to 41 cm. The mollic epipedons were black with moist value of 2, chromas of 1 to 2, and soil pH values ranging from 5.6 to 5.8. The thickness of the horizons with > 10 g kg^{-1} organic matter ranged from 76 to 79 cm. Group I soils have cambic horizons with thickness ranging from 20-48 cm, values equal to 4, chromas equal to 2, and pH ranging from 6.2 to 6.6. The thickness of the Bg horizon ranged from 15 cm to 36 cm. The Bg horizon had values ranging from 4 to 6, chromas ranging from 2 to 4, and pH ranging from 6.7 to 7.1. The dominant redoximorphic features in these soils in Gordon's Marsh are olive brown (2.5Y 4/4) to yellowish brown (10YR 5/8) mottles.

The summit soil along transect 3 in Gordon's Marsh was classified as a Nicollet (Table 45). The depth to redoximorphic features was 69 cm, and the depth to free carbonates was 102 cm. The thickness of the mollic epipedon was 41 cm. The mollic epipedon had moist values of 2, moist chromas of 1, and pH ranging from 5.3 to 6.0. The thickness of the Bw horizons was 28 cm. The Bw horizons had moist values of 4, moist chromas of 2, and pH values ranging from 6.4 to 6.7. The thickness of the Bg horizon was 15 cm. The Bg horizon had moist value of 4, moist chroma of 2, pH values equal to 7.1, and high chroma mottles. The cumulative thickness of horizon with >10 g kg^{-1} organic matter was 53 cm. The upper 200 cm of the pedon were never saturated, suggesting redoximorphic features in the pedon are relict.

James and Fenton (1993) reported the water table in Clarion soils on an undrained Mollisol hillslope ranged from 130 to 340 cm, with shallowest depths occurring in April to June and deepest depths occurring in January to March. A water table was present from 100-150 cm 19% of the time and 100% of the time from 150-340 cm. In the same study, the water table in the Clarion soils on the drained hillslope ranged from 120 to 340 cm. A water table was present from 100-150 cm 26% of the time. They concluded that the Clarion soils are forming in an oxidizing environment. Khan and Fenton (1994) reported the water table in Clarion soils on an artificially drained hillslope ranged from 107 to 318 cm. The water table was present from 100-150 cm 19-21% of the time. The soils on restored prairie summits had greater shallowest water table depths than the artificially drained summits. Steinwand and Fenton (1995) also grouped soils on Mollisol hillslopes based on soil morphology and slope position. Group I soils (Clarion) were analogous with Group I soils developed in this study. Group I group encompassed well drained soils on summit and shoulder positions. These soils lacked Fe-depleted matrices and were saturated 34% of the time. High chroma redoximorphic features were present above or in the same horizon as redox depletions, reflecting periodic saturation. Group I soils in the upland prairie summits and shoulder also had the same trend.

Soil Hydromorphology of Group II soils.

Mean annual water table depths ranged from 64 to 151 cm below the soil surface in Colo Bog (Table 9). Shallowest annual water table depths ranged from 3 to 38 cm below the soil surface. Mean annual water table depths ranged from 98 to 158 cm below the soil surface in Harrier's Marsh. Shallowest annual water table depths ranged from 10 to 15 cm below the soil surface. Mean annual water table depths ranged from 90 to 127 cm below the soil surface in Gordon's Marsh (Table 11). Shallowest annual water table depths ranged from 3 to 76 cm below the soil surface. Mean annual water table depths for soils on backslopes on the drained transect in Gordon's Marsh ranged from 174 to 185 cm below the soil surface. Shallowest annual water table depth ranged from 41 to 69 cm below the soil surface.

The water table was observed 0 to 11% of the time from 0-25 cm, 8 to 26% from 25-50 cm, 21 to 36% from 50-75 cm, 24 to 88% from 75-100 cm, 44 to 69% from 100-125 cm, 61 to 80% from 125-150 cm, 75 to 90% from 150-175 cm, and 67 to 100% from 175-200 cm in Colo Bog (Table 12). The water table was observed 4 to 8% of the time from 0-25 cm, 8 to 20% from 25-50 cm, 12 to 38% from 50-75 cm, 35 to 65% from 75-100 cm, 46 to 69% from 100-125 cm, 56 to 73% from 125-150 cm, 65 to 78% from 150-175 cm, and 69 to 92% from 175-200 cm in Harrier's Marsh (Table 13). The water table was observed 0 to 8% of the time from 0-25 cm, 2 to 13% from 25-50 cm, 4 to 25% from 50-75 cm, 17 to 67% from 75-100 cm, 36 to 79% from 100-125 cm, 88 to 92% from 125-150 cm, 92 to 100% from 150-175 cm, and 100% from 175-200 cm in Gordon's Marsh (Table 14). The water table was observed 0% of the time from 0-25 cm, 5% from 25-50 cm, 7% from 50-75 cm, 12% from 75-100 cm, 14% from 100-125 cm, 19% from 125-150 cm, 21% from 150-175 cm, and 27% of the time from 175-200 cm in backslope soils on transect 3 in Gordon's Marsh (Table 14).

The depth to redoximorphic features ranged from 15 to 71 cm in Group II soils in Colo Bog (Tables 16, 19, 23). Low chroma (≤2) mottles were common in the upper 100 cm of the soil profile and these horizons were saturated 4 to 63% of the time. High chroma (≥2) mottles and Mn concretions were common in the lower Bg horizons and the upper C horizons. Depth to free carbonates varied ranging from 89 to >200 cm. The thickness of the mollic epipedon varied from 30cm on upper backslopes to 76 cm on lower backslope positions. The mollic epipedons had moist values of 2 to 3, moist chromas of 0 to 2, and pH values ranging from 5.0 to 6.8. Nine pedons were assigned to Group II soils in Colo Bog. Three pedons were classified as Nicollet soils and had Bw horizons. Five of the other pedons were in the range of Delft and Webster and had Bg horizons. Thickness of the Bw horizons in the Nicollet soils ranged from 14 to 28 cm with moist values of 4, moist chromas of 2 and 4, and pH values ranging from 6.6 to 7.1. Thickness of the Bg horizons in all 9 pedons ranged from 13 to 38 cm. The Bg horizons had moist values of 3 to 6, moist chromas of 1 to 3, and pH values ranging from 6.5 to 8.2. The cumulative thickness of all horizons with over 10 g kg^{-1} organic matter ranged from 38 to 86 cm.

Four pedons were assigned to Group II soils in Harrier's Marsh (Tables 27, 31, and 35). The soils were classified as Nicollet, Canisteo, and Delft. Depth to redoximorphic features ranged from 48 to 99 cm. Depth to free carbonates ranged from 79 to 122 cm. The thickness of the mollic epipedons ranged from 48 to 81 cm. The mollic epipedons had moist values of 2 and 3, moist chromas of 0 and 1, and pH values ranging from 5.8 to 7.9. The high pH values in the mollic epipedons are present in the calcareous Canisteo soils. Thickness of the Bg horizons ranged from 16 to 43 cm. These horizons had moist values of 3 to 6, moist chromas of 0 to 2, and pH values ranging from 7.2 to 8.3. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 48 to 97 cm. Low chroma redoximorphic features were common in the upper 80 cm of the sola. High chroma mottles and Mn concretions were abundant in the lower parts of the sola and the Cg horizons. Depth at which redoximorphic features occurred were saturated 16 to 65% of the time.

Three pedons were assigned to Group II soil in Gordon's Marsh (Tables 39 and 42). Two of the pedons were in the range of the Webster series and the third pedon was classified as Delft. Delft soils have similar morphological properties as Webster soils except the Delft soils have a cumulic mollic epipedon. The depth to redoximorphic features ranged from 0 to 74 cm. Each pedon differed in redoximorphic features. The Webster pedon in transect 1 had high chroma mottles in the lower solum, whereas the Delft soil downslope had low chroma redoximorphic features in the upper solum. Depths at which redoximorphic features occurred in the Webster soil are saturated approximately 13% of the time. The horizons with low chroma redoximorphic features (79 cm thick) in the Delft soil were never saturated during the monitoring period, reflecting relict features. The lower horizons with mixture of high and low chroma redoximorphic features were saturated over 13% of the time. The Webster soil in transect 2 had a mixture of low and chroma redoximorphic features in the solum. Depths at which these features occurred were saturated approximately 8 to 25% of the time. The depth to free carbonates ranged from 81 to 107 cm. The thickness of the mollic epipedon ranged from 46 to 79 cm. The mollic epipedons had moist values of 2 to 3, moist chromas of 0 and 1, and pH values ranging from 6.3 to 7.6. Thickness of the Bg horizons ranged from 23 to 35 cm. These horizons had moist values of 4 to 6, moist chromas of 1 and 2, and pH values ranging from 7.3 to 8.2. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 53 to 107 cm.

The backslope soils on the drained transect in Gordon's Marsh were classified as Delft (Table 45). These soils had cumulic mollic epipedons 79 to 86 cm thick. The depth to redoximorphic features ranged from 36 to 74 cm. The depth to free carbonates ranged from 99 to 178 cm. The mollic epipedon had moist values of 2 and 3, moist chromas of 0 and 1, and pH values ranging from 5.8 to 6.9. The thickness of the Bg horizons ranged from 35 to 53 cm. These horizons had moist values of 3 and 4, moist chromas of 1 and 2, and pH values ranging from 6.1 to 7.8. Low chroma mottles were present in the lower horizons of the mollic epipedon. High chroma mottles were common in the lower horizons of the sola. In contrast to the summit soils, depths at which redoximorphic features occurred were saturated 9 to 14% of the time.

Nicollet soils occurred on backslopes in the hydromorphology studies by Khan and Fenton (1994), and Nicollet and Webster soils occurred on the backslopes in the study by James and Fenton (1993). Khan and Fenton (1994) reported this soil was intermediate in degree of development of the gray matrix. The water table ranged from 100 to 156 cm and was present from 50-100 cm approximately 27% of the time and 85% from 100-150 cm. Dark grayish brown matrices with high chroma mottles and Mn concretions reflected a fluctuating water table. James and Fenton (1993) reported undrained Nicollet soil had water table ranging from 90-170 cm. The water table was present from 75-100 cm 11% of the time, 83% from 100-150, and 100% below 180 cm in the undrained Nicollet soil. The water table in the undrained Webster soil was shallower, ranging from 50 to 170 cm. The water table was present 8% of the time from 50-75 cm, 56% from 75-100 cm, and 100% from 150 cm on. The water table in the drained Nicollet soil ranged from 100 to 300 cm but ranged from 100 to 150 cm in the drained Webster soil. Steinwand and Fenton (1995) reported backslope soils on drained hillslopes had horizons with common redox depletions or Fe depleted matrices and were saturated 20.5% of the time. Horizons below the above mentioned horizons had common to many high chroma redoximorphic features, suggesting translocation of Fe to underlying B and C horizons and subsequent formation of poorly crystalline or amorphous Fe oxides. The soils in our study correlated with the findings of Khan and Fenton (1994) and Steinwand and Fenton (1995). The Group II soils in our study had low chroma mottles in the upper horizons, Fe depleted matrices in the sola, mixture of low and high chroma mottles in lower B horizons, and the dominance of high chroma mottles in lower C horizons. The presence of cumulic mollic epipedons on the prairie backslopes are due to a combination of past erosional/depositional processes and increased aboveground and belowground biomass turnover of the prairie ecosystem.

Soil Hydromorphology of Group III soils.

Mean annual water table depths ranged from 51 to 72 cm below the soil surface in Colo Bog (Table 9). Shallowest annual water table depths ranged from 5 to 20 cm below the soil surface. Mean annual water table depths ranged from 35 to 93 cm below the soil surface in Harrier's Marsh (Table 10). Shallowest annual water table depths ranged from 3 to 41 cm above the soil surface. Mean annual water table depths ranged from 40 to 82 cm below the soil surface in Gordon's Marsh (Table 11). Shallowest annual water table depths ranged 18 cm below the soil surface to 38 cm above the soil surface. The soils on footslopes of transect 3 in Gordon's Marsh had mean annual water table depth 135 cm below the soil surface. Shallowest water table depth was 15 cm below the soil surface.

The water table was observed 17 to 23% of the time from 0-25 cm, 46 to 49% from 25-50 cm, 61 to 63% from 50-75 cm, 63 to 77% from 75-100 cm, 88 to 91% from 100-125 cm, 88 to 99% from 125-150 cm, and 100% from 150-200 cm in Colo Bog (Table 12). The water table was observed 31 to 58% of the time from 0-25 cm, 50 to 62% from 25-50 cm, 62 to 74% from 50-75 cm, 64 to 81% from 75-100 cm, 65 to 90% from 100-125 cm, 73 to 91% from 125-150 cm, 77 to 100% from 150-175 cm, and 83 to 100% from 175-200 cm in Harrier's Marsh (Table 13). The water table was observed 13 to 25% of the time from 0-25 cm, 25 to 40% from 25-50 cm, 48 to 58% from 50-75 cm, 78% from 75-100 cm, 88 to 90% from 100-125 cm, 92 to 100% from 125-150 cm, 97 to 100% from 150-175 cm, and 100% from 175-200 cm in Gordon's Marsh (Table 14). The water table was observed 9% of the time from 0-25 cm, 23% of the time from 25-50 cm, 23% of the time from 50-75 cm, 36% of the time from 75-100 cm, 41% of the time from 100-125 cm, 41% of the time from 125-150 cm, 59% of the time from 150-175 cm, and 59% of the time from 175-200 cm in the footslope soil on transect 3 in Gordon's Marsh (Table 14).

Four pedons were assigned to Group III soils in Colo Bog. Three of the pedons were within the range of the Canisteo series and other was a Delft-Canisteo intergrade. The depth to redoximorphic features ranged from 0 to 38 cm (Tables 20 and 24). The depth to free carbonates ranged an upper depth of 38 cm to >200 cm. The thickness of the mollic epipedons ranged from 41 to 71 cm. The mollic epipedons had moist values of 2 to 3, moist chromas of 0 to 1, and pH values ranging from 7.6 to 8.2. The thickness of the Bg horizons ranged from 23 to 46 cm. These horizons had moist values of 3 to 6, moist chromas of 1 and 2, and pH values ranging from 7.7 to 8.3. The thickness of the horizons with greater than 10 g kg^{-1} organic matter ranged from 41 to 71 cm, equivalent to the thickness of the mollic epipedons. Low chroma mottles and Fe depletions were present in the upper 80 cm of the soil profile in these soils. High chroma mottles were abundant in the lower Bg and Cg horizons.

Seven pedons were assigned to Group III soils in Harrier's Marsh. Six of the pedons were classified as Canisteo and the other pedon was classified as a Harps. The depth to redoximorphic features ranged from 18 to 71 cm (Tables 28, 32, and 36). The Harps soil had a Bkg horizon at 71 cm. The thickness of the mollic epipedons ranged from 23 to 86 cm. The mollic epipedons had moist values of 2 to 3, moist chromas of 0 to 1, and pH values ranging from 7.2 to 8.2. The Bg horizons had thickness ranging from 20 to 35 cm, moist values of 3 to 6, moist chromas of 0 to 2, and pH values ranging from 7.6 to 8.3. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 51 to 86 cm. Low chroma mottles, Fe depletions, and high chroma pore linings were common in the sola of Group III soils in Harrier's Marsh.

Five pedons were assigned as Group III soils in Gordon's Marsh. Three of the soils were classified as Canisteo soils and two as Delft soils. The Delft pedons differed from the Canisteo soils in that the Delft soils had silty clay loam textures in the sola and have cumulic mollic epipedons. However, the Delft soils have alkalinity similar to the Canisteo soils. Morphology of the Delft pedons indicates cumulization of organo-silt and clay particles during past hillslope erosional processes. The depth to redoximorphic features ranged from 0 to 74 cm (Tables 40 and 43). The minimum depth to free carbonates was 46 cm in the Canisteo soils. The Delft soils did not have free carbonates to a depth of 200 cm. The thickness of the mollic epipedon ranged from 46 to 89 cm. The mollic epipedons had moist values of 2 and 3, moist chromas of 0 to 1, and pH values ranging from 7.3 to 8.1. The thickness of the Bg horizons ranged from 13 to 41 cm. The Bg horizons had moist values of 3 to 6, moist chromas of 1 to 2, and pH values ranging from 7.7 to 8.2. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 48 to 89 cm. In general, the upper 50 cm of the pedons had low chroma mottles, Fe depletions, and pore linings. The lower 50 cm had high chroma mottles and pore linings.

The soil on the footslope in transect 3 in Gordon's Marsh was classified as a Canisteo (Table 46). The depth to redoximorphic features was 15 cm. The thickness of the mollic epipedon was 53 cm. The mollic epipedon had moist values of 2, moist chroma of 0, and pH from 7.1 to 7.7. The thickness of the Bg horizons was 36 cm. The Bg horizons had moist values of 3 to 5, moist chromas of 1, and soil pH of 7.9. Low chroma mottles were abundant in the upper 70 cm of the solum. High chroma mottles were common in the lower solum and the Cg horizons.

Undrained footslope soils in the study by James and Fenton (1993) had water table depths ranging from 25 to 125 cm in Canisteo soils and 20 to 91 cm in Harps soils. The water tables occurred 6% of the time from 0-40cm, 75% from 40-75, 86% from 75-100 cm, and 100% from 120 cm on in the undrained Canisteo soils. In the undrained Harps soils, the water table occurred 17% of the time in the A2 horizon and 72% from 33-76 cm. James and Fenton (1993) reported tile drainage lowered the water table to 100 cm depth 100% of the time in the Canisteo soil and to 40 cm depth 100% of the time. Khan and Fenton (1994) found the water table was present in the drained Canisteo 5% of the time from 0-50 cm, 79% from 50-100 cm, and 100% from 100 cm on.

<u>Soil Hydromorphology of Group IV soils.</u>

Mean annual water table depths ranged from 35 cm below the soil surface to 26 cm above the soil surface in Colo Bog (Table 9). Shallowest annual water table depths ranged from 5 to 66 cm above the soil surface. Mean annual water table depths ranged from 16 to 34 cm below the soil surface in Harrier's Marsh (Table 10). Shallowest water table depths ranged from 48 to 66 cm above the soil surface. Mean annual water table depths ranged from 20 cm above the soil surface to 41 cm below the soil surface in Gordon's Marsh (Table 11). Shallowest water table depths ranged from 51 to 74 cm above the soil surface. In contrast, the Klossner soil (Histosol) in the pond depression of transect 3 in Gordon's Marsh had soil mean annual water table depths ranging from 26 to 103 cm below the soil surface. Shallowest water table depths ranged from 20 cm below the soil surface to 56 cm above the soil surface. Deepest water table depths were greater than 137 cm.

The water table was observed 46 to 75% of the time from 0-25 cm, 63 to 92% from 25-50 cm, 88 to 100% from 50-75 cm, 92 to 100% from 75-100 cm, and 100% from 100-200 cm in Colo Bog (Table 12). The water table was observed 35 to 62% of the time from 0-25 cm, 62 to 73% from 25-50 cm, 65 to 96% from 50-75 cm, 65 to 100% from 75-100 cm, 73 to 100% from 100-125 cm, 87 to 100% from 125-150 cm, and 100% of the time from 150-200 cm in Harrier's Marsh (Table 13). The water table was observed 44 to 88% of the time from 0-25 cm, 50 to 92% from 25-50 cm, 88 to 100% from 50-75 cm, 92 to 100% from 75-100 cm, 96 to 100% from 100-125 cm, and 100% from 125-200 in Gordon's Marsh (Table 14). The water table was observed 39% of the time from 0-25 cm, 45% from 25-50 cm, 55% from 50-75 cm, 58% from 75-100 cm, 67% from 100-125 cm, 77% from 125-150 cm, 89% from 150-175 cm, and 95% from 175-200 cm in the pond soils on transect 3 in Gordon's Marsh (Table 14).

Four pedons were assigned to Group IV soils in Colo Bog. One of the pedons was within the range of the Okoboji series. Two pedons were classified as Glencoe and Canisteo, and the other pedon was a Canisteo-Okoboji intergrade. The depth to redoximorphic features ranged from 0 to 28 cm (Tables 17, 21, and 25). Depths at which redoximorphic features occurred were saturated 46 to 100% of the time. The minimum depth to free carbonates was 165 cm. The thickness of the mollic epipedons varied from 61 to 137 cm. The mollic epipedons in these soils had moist values of 2 to 3, moist chromas of 0 to 1, and pH values ranging from 6.8 to 8.0. The Bg horizons had thickness ranging from 17 to 33 cm, moist values of 3 to 5, moist chromas of 0 to 2, and pH values ranging from 7.1 to 7.8. The cumulative thickness of horizons with greater than 10 g kg^{-1} organic matter ranged from 61 to 137 cm, equivalent to the thickness range of the mollic epipedons. The textures in the sola of the soils ranged from clay loam to silty clay loam. The sola in all these soils had low chroma mottles, Fe depletions, and high chroma mottles.

Five pedons were assigned to Group IV soils in Harrier's Marsh. Four of the pedons were within the range of the Okoboji series, and one pedon classified as Canisteo. The depth to redoximorphic features ranged from 0 to 43 cm (Tables 29, 33, and 37). The minimum depth to free carbonates was 89 cm. The thickness of the mollic epipedons ranged from 53 to 104 cm. Mollic epipedons were dark with moist values of 2 to 3, moist chromas of 0 to 1, and pH values ranging from 6.0 to 7.7. The Bg horizons were gray with moist values of 3 to 6, moist chromas of 0 to 2, and pH values ranging from 7.0 to 8.0. The thickness of the Bg horizons ranged from 18 to 58 cm. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 53 to 104 cm. The sola of these soils had low chroma mottles, high chroma mottles, and high chroma pore lining in the upper horizons.

Three pedons were assigned to Group IV soils on the undrained hillslope in Gordon's Marsh. Two of the pedons were classified as Okoboji, and the other pedon was classified as Wacousta. In previous soil maps, the Wacousta soil was classified as a Palms soil (Terric Haplosaprist). This pedon had now more Mollisol characteristics. The pedon lacked an O horizon necessary for Histosol classification. The depth to redoximorphic features ranged from 13 to 15 cm (Tables 41, 44, and 46). The depth to free carbonates ranged from 41 to 97 cm in transect 1. The Okoboji pedon in transect 2 did not have free carbonates to a depth of 200 cm. The thickness of the mollic epipedon ranged from 23 (Wacousta soil) to 86 cm. The mollic epipedon had moist values of 2 to 3, moist chromas of 0 to 1, and pH values ranging from 6.6 to 7.8. The Bg horizons had a thickness ranging from 11 to 18 cm, moist values of 4 to 5, moist chromas of 1 and 2, and pH values ranging from 7.5 to 8.0. The cumulative thickness of horizons with over 10 g kg^{-1} organic matter ranged from 23 to 86 cm. Low chroma mottles and pore linings were present in the lower A horizon of these soils. High chroma mottles and pore linings were common in the lower A horizons. High chroma mottles were also abundant in the Bg and Cg horizons.

The soils on the pond depression along transect 3 in Gordon's Marsh were classified as Klossner. These soils are Histosols (Terric Haplosaprist). They had thin O horizons ranging from 5 to 25 cm thick with organic matter contents greater than 35 g kg^{-1}. The minimum thickness of the mollic epipedon was 79 cm. High and low chroma mottles and pore linings were common in the lower horizons of the sola.

The undrained Okoboji soil in the study by James and Fenton (1993) had water table depths ranging from 40cm below to 55 cm above the soil surface. The water table was present 92% of the time from 0 to 40 cm. Artificial drainage lowered the water table to 40 cm 100% of the time in the Okoboji on the drained catena, suggesting soil horizons above this depth are forming in oxidizing environments. The water table was present 1% of the time from 0-65 cm, 9% of the time from 65-85 cm, and 55% of the time from 85-100 cm in drained toeslope soils in the study by Steinwand and Fenton (1995). The drained Knoke soil in the study by Khan and Fenton (1994) had water tables present 7% of the time from 0-50 cm, 79% of the time from 50-100 cm, and 100% of the time from 100 cm on. In general, the toeslope soils exhibited the similar range in water table depths as that reported by James and Fenton (1993) on undrained hillslopes. The drainage ditch in transect 3 appeared to significantly alter the water table status for summit and backslope soils but had less affect on the Canisteo and Klossner soils.

Table 15. Selected soil morphology and characterization data for Group I soils on transect 1 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Clarion loam-Upland Prairie-Summit							
A1	0-18	10YR 2/1	-	5.5	4.8	-	39.0	38.8	22.2	L
A2	18-43	10YR 3/1	-	6.1	3.2	-	22.5	48.9	28.6	CL
A3	43-56	10YR 3/1	-	6.4	2.0	-	17.7	52.3	30.0	SiCL
AB	56-74	10YR 3/2, 3/3	-	6.4	1.3	-	21.5	48.8	29.7	CL
Bw1	74-86	10YR 4/2	-	6.6	0.7	-	52.6	26.8	20.6	SaL
Bw2	86-97	10YR 4/2	-	6.3	0.6	-	70.9	15.1	14.0	SaL
Bw3	97-102	10YR 4/2, 4/4 5/2	-	6.9	0.3	-	54.6	28.9	16.5	SaL
Bw4	102-109	10YR 4/2, 4/4	-	6.8	0.5	-	73.8	13.5	12.7	SaL
C1	109-135	2.5Y 5/2	common fine 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	7.4	0.4	9	49.2	31.8	19.0	L
C2	135-188	2.5Y 4/4	few fine-coarse 2.5Y 5/2 Fe dep. few fine 10YR 4/6 mottles	7.9	-	28	48.8	33.4	17.8	L
C3	188-226	2.5Y 5/2	few medium 2.5Y 5/2 Fe dep. few fine 10YR 4/6 mottles	8.0	-	19	53.0	30.6	16.4	SaL
			Nicollet loam-Upland Prairie-Summit							
A1	0-20	10YR 2/1	-	5.4	4.8	-	28.1	46.7	25.2	L
A2	20-43	10YR 3/1	-	5.6	3.0	-	22.6	48.7	28.7	CL
A3	43-58	10YR 3/1	-	5.6	1.7	-	22.9	46.8	30.3	CL
Bg1	58-66	2.45Y 4/2	few fine 10YR 5/8, 2.5Y 5/6 mott	5.7	1.0	-	28.5	43.8	27.7	CL
Bg2	66-79	2.5Y 4/2	common fine 2.5Y 4/4 mottles 10YR 3/6 concretions	6.3	0.6	-	52.8	30.2	17.0	SaL
Cg1	79-122	2.5Y 4/2 & 4/4	-	7.1	-	5	80.2	12.2	7.6	LS
Cg2	122-140	2.5Y 5/2 & 4/4	few coarse 10YR ¾ mottles	7.9	-	9	79.9	14.2	5.9	LS
2Cg	140-183	2.5Y 4/4, 5/4, 6/4, 6/2	few fine 10YR 5/4 & 5/8 mottles	8.0	-	17	60.9	31.6	7.5	SaL

Table 16. Selected soil morphology and characterization data for Group II soils on transect 1 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Nicollet loam-Upland Prairie-Backslope							
A1	0-18	10YR 2/1	-	5.4	4.3	-	33.6	41.2	25.2	L
A2	18-30	10YR 3/1	-	5.6	3.6	-	23.6	36.5	39.9	CL
AB	30-46	10YR 3/3	-	5.9	2.1	-	26.6	44.2	29.2	CL
Bw1	46-58	10YR 4/3	-	6.6	1.1	-	38.1	37.1	24.8	L
Bw2	58-71	2.5Y 4/4	-	7.1	0.6	4	51.6	29.3	19.1	L
Bg	71-89	2.5Y 5/2	common fine 2.5Y 4/4 few fine 10YR 4/6 mottles Mn concretions	7.6	0.8	7	52.1	28.7	19.2	L
Ckg1	89-102	2.5Y 6/2	few fine 2.5Y 5/6, 10YR 4/6 mo.	8.2	-	20	38.9	39.7	21.4	L
Ckg2	102-119	2.5Y 6/2 & 5/4	few fine 2.5Y 5/6 mottles Mn concretions	8.4	-	24	33.6	41.4	25.0	L
Ckg3	119-140	2.5Y 6/2	common f/m 2.5Y 5/4 mottles few fine 10YR 5/8, 4/6 mottles Mn concretions	8.3	-	22	39.7	39.4	20.9	L
Cg1	140-173	2.5Y 6/2	common f/m 2.5Y 5/4 mottles few fine 10YR 4/6 mottles 7.5YR 5/8 concretions	8.3	-	25	42.4	38.9	18.7	L
Cg2	173-226	2.5Y 5/2	many medium 2.5Y 5/4 mottles Mn and 7.5YR 5/8 concretions	8.3	-	21	48.3	33.9	17.8	L
			Well 4: Nicollet loam-Upland Prairie-Backslope							
A1	0-23	10YR 2/2	-	5.4	4.7	-	29.1	45.9	25.0	L
A2	23-48	2.5Y 2/1	-	6.1	3.9	-	22.3	47.6	30.1	CL
Bw	48-76	2.5Y 4/2	-	6.6	1.9	-	31.8	39.1	29.0	CL
Bg1	76-94	2.5Y 4/2	few fine 2.5Y 4/4 mottles	7.3	0.7	1	45.2	29.3	25.5	L
Bg2	94-109	2.5Y 4/2 & 5/2	common fine 2.5Y 5/4 mottles few fine 10YR 5/8 mottles	7.4	0.7	10	51.1	26.3	22.6	L
BCg	109-124	2.5Y 4/1 & 5/2	few fine 2.5Y 5/4 & 4/4 mottles Mn and 7.5YR 4/6 concretions	7.7	0.4	11	51.6	27.3	21.1	L
Cg1	124-150	2.5Y 5/2	common fine 2.5Y 4/4, 5/4 mott. few fine 10YR 5/8 mottles Mn concretions	8.1	-	10	49.7	30.4	19.9	L
Cg2	150-160	2.5Y 5/2	common fine 2.5Y 5/4, 4/4 mott. few fine 10YR 4/6 mottles Mn concretions	8.2	-	15	50.9	32.2	16.9	L
Cg3	160-208	2.5Y 5/4	few medium 2.5Y 5/2 Fe dep. Mn and 7.5YR 4/6 concretions few fine 10YR 4/6 mottles	8.2	-	15	48.3	35.0	16.7	L

Table 16. (continued).

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 5: Webster loam-Upland Prairie-Backslope							
A1	0-18	2.5Y 2/0	few fine 2.5Y 3/2 mottles	5.3	4.0	-	29.8	43.8	26.4	L
A2	18-28	2.5Y 3/2	few fine 10YR 3/3 mottles	5.8	2.2	-	33.4	38.5	28.1	CL
AB	28-41	2.5Y 4/3 & 3/2	few fine 7.5YR ¾ mottles	6.2	1.3	-	42.7	31.2	26.1	L
Bg1	41-53	2.5Y 4/2 & 4/4	few fine 7.5YR ¾ mottles	6.4	0.8	-	47.9	28.5	23.6	L
Bg2	53-76	2.5Y 4/2	few fine 10YR ¾ mottles Mn concretions	7.0	0.4	2	50.5	28.1	21.4	L
Bg3	76-89	2.5Y 4/2	common fine 2.5Y 5/4 mottles few Mn and 10YR ¾ concretions	7.5	0.5	3	50.8	29.0	20.2	L
Cg1	89-97	2.5Y 5/2 & 4/2	many fine 2.5Y 5/4 mottles few fine 10YR 5/8 & 5/6 mottles few Mn and 7.5YR ¾ concretions	8.0	-	9	51.0	30.6	18.4	L
Cg2	97-127	2.5Y 5/2	common medium 2.5Y 5/4 mott. few Mn and 7.5YR ¾ concretions	8.1	-	15	49.4	33.0	17.6	L
Cg3	127-155	2.5Y 5/2	many fine 2.5Y 5/4 mottles few fine 10YR 4/6 mottles few Mn and 7.5YR ¾ concretions	8.2	-	16	49.9	33.2	16.9	L
Cg4	155-175	2.5Y 5/2	common medium 2.5Y 5/4 mott. few fine 10YR 4/6 mottles Mn concretions	8.3	-	17	48.6	35.4	16.0	L
Cg5	175-196	2.5Y 5/2	many f/m 2.5Y 5/4 mottles common fine 7.5YR 5/8 mottles few Mn concretions	8.3	-	29	48.9	34.4	16.7	L
			Well 6: Webster clay loam-Upland Prairie-Backslope							
A1	0-8	N 2/0	-	7.3	7.0	2	35.3	35.9	28.8	CL
A2	8-25	2.5Y 2/0	-	6.0	4.7	0	41.5	41.0	17.5	L
A3	25-48	2.5Y 2/0	-	6.7	3.4	0	29.9	40.5	29.6	CL
Bg1	48-71	2.5Y 3/1	-	7.3	0.8	3	33.0	39.9	27.1	CL
Bg2	71-84	5Y 3/1 & 4/1	few fine 5Y 5/2 Fe depletions	7.8	0.7	2	36.0	39.2	24.8	L
BCg	84-107	5Y 3/1 & 4/1	common fine 5Y 6/2 Fe dep. few f/m 10YR 4/6 mottles	8.0	0.4	5	31.5	53.5	15.0	SiL
Cg	107-112	5Y 6/2 & 4/1	few fine 10YR 4/6 mottles	8.0	-	10	31.4	43.1	25.5	L
2Cg1	112-132	5Y 6/2 & 4/1	many c 10YR 4/6, 2.5Y 4/4 mot few Mn concretions	8.1	-	14	52.0	32.4	15.6	L
2Cg2	132-168	5Y 6/2, 4/1, 5/1	many coarse 2.5Y 4/4 mott. 10YR ¾ fracture linings few Mn concretions	8.3	-	19	51.2	34.5	14.3	L
2Cg3	168-198	5Y 5/1	common f/m 2.5Y 4/4 mott. few 10YR ¾ fracture linings few fine 7.5YR ¾ mottles	8.2	-	19	49.0	33.7	17.3	L

Table 17. Selected soil morphology and characterization data for Group IV soils on transect 1 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 7: Canisteo loam-Pond Depression-Footslope							
A1	0-25	N 2/0	few fine 5Y 6/2 Fe depletions	7.5	5.5	7	34.8	39.7	25.5	L
A2	25-43	N 2/0	few fine 2.5Y 4/2, 5Y 4/1 Fe depl	7.7	3.0	4	31.5	42.5	26.0	L
A3	43-61	N 2/0	few fine 2.5Y 4/4 mottles few fine 5Y 4/1 Fe depletions	7.7	1.3	2	27.0	46.1	26.9	L
Bg1	61-86	5Y 5/1, 4/1	few fine 2.5Y 4/4 mottles	7.6	0.4	4	16.4	52.6	31.0	SiCL
Bg2	86-109	5Y 5/1, 4/1	many fine 2.5Y 4/4 mottles common fine 10YR 5/8 mottles few 7.5YR ¾ pore linings	7.7	0.2	9	24.9	46.6	28.5	CL
2Cg	109-127	5Y 5/1, 4/1	few fine 2.5Y 4/4 mottles	7.9	-	10	71.5	15.8	12.7	SaL
3Cg	127-152	5Y 5/1, 4/1	many f/m 2.5Y 4/4 mottles common fine 10YR 5/8 mottles few fine 7.5YR ¾ mottles	7.9	-	12	55.0	24.9	20.1	SaL
4Cg	152-175	2.5Y 4/2, 5Y 4/1	few fine 2.5Y 4/4, 7.5YR ¾ mott.	8.1	-	12	65.0	20.7	14.3	SaL
5Cg	175-203	5Y 4/1	few coarse 2.5Y 4/4 mottles few fine 7.5YR ¾ mottles	7.9	-	16	51.3	31.9	16.8	L
			Well 8: Canisteo-Okoboji loam-Pond Depression-Footslope							
A1	0-18	N 2/0	common fine 2.5Y 4/1Fe depl	7.8	5.2	5	38.4	37.1	24.5	L
A2	18-41	2.5Y 2/0	many fine 7.5YR 2/4 mottles few f/m 5Y 5/2 Fe depletions	7.8	6.1	5	35.3	39.0	25.7	L
A3	41-76	2.5Y 2/0	-	7.5	4.4	2	21.8	51.8	26.4	SiL
A4	76-94	2.5Y 2/0	few fine 2.5Y 4/2 & 4/4 mottles	8.0	2.8	7	30.6	43.4	26.0	L
2A5	94-114	2.5Y 2/0	few fine 2.5Y 4/4 mottles	7.6	1.7	2	7.4	60.3	32.3	SiCL
2A6	114-137	2.5Y 2/0	few fine 2.5Y 4/4 mottles many coarse 5Y 5/1 Fe depletions	7.9	1.0	3	6.8	60.2	33.0	SiCL
2Bg	137-165	5Y 5/1	many fine 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	7.8	-	13	8.1	60.6	31.3	SiCL
2Ckg	165-206	5Y 5/1	common fine 2.5Y 4/4 mottles few fine 7.5YR ¾, 10YR 4/6 mo.	8.0	-	19	8.9	65.5	25.6	SiL

Table 18. Selected soil morphology and characterization data for Group I soils on transect 2 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Nicollet loam-Upland Prairie-Shoulder-Backslope							
A1	0-10	2.5Y 2/1	-	6.1	4.5	-	33.5	38.8	24.7	L
A2	10-33	2.5Y 2/1	-	5.4	4.3	-	27.7	43.6	28.7	CL
A3	33-46	10YR 2/1	-	5.7	3.3	-	26.7	43.0	30.3	CL
A4	46-53	10YR 2/1	-	6.0	3.0	-	31.7	39.9	28.4	CL
Bw1	53-64	10YR 3/2	-	6.1	1.5	-	37.7	34.2	28.1	CL
Bw2	64-89	10YR 3/3	-	6.2	0.7	-	45.2	29.4	25.4	L
BCg	89-109	2.5Y 4/4	few fine 7.5YR ¾ mottles	7.0	0.7	-	48.2	28.2	23.6	L
Cg1	109-122	2/5Y 4/4	few fine 2.5Y 4/2, 5/2, 7.4YR ¾ mo	7.8	0.3	2	49.5	29.1	21.4	L
Ckg1	122-130	2/5Y 4/4	few fine 2.5Y 5/2 & 4/2 Fe depl.	7.6	-	13	48.2	31.9	19.9	L
Cg2	130-147	2.5Y 4/4	few medium 2.5Y 5/2 Fe depl few fine 10YR 5/8 and 7.5YR ¾ mo	8.2	-	15	49.1	33.0	17.9	L
Ckg2	147-175	2.5Y 4/4	common medium 2.5Y 5/2 Fe dep few fine 10YR 5/8 and 7.5YR ¾ mo Mn concretions	8.2	-	20	38.4	36.2	25.4	L
2Cg	175-196	2.5Y 5/4 & 4/4	few fine 2.5Y 5/2 Fe depletions few fine 10YR 5/8 and 7.5YR ¾ mo	8.3	-	16	62.4	26.8	10.8	SaL

Table 19. Selected soil morphology and characterization data for Group II soils on transect 2 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 2: Deft loam-Upland Prairie-Backslope							
A1	0-15	2.5Y 2/1	-	5.8	5.5	-	30.5	45.3	24.2	L
A2	15-30	2.5Y 2/1	-	5.7	4.4	-	29.7	43.7	26.6	L
A3	30-53	2.5Y 2/1	-	6.1	3.6	-	32.8	39.9	27.3	CL
A4	53-66	2.5Y 2/1	few fine 10YR 3/2 & 5/8 mottles	6.3	2.4	-	36.4	37.0	26.6	L
Bg1	66-84	10YR 3/3	few fine 10YR 5/8 mottles	6.6	0.9	-	42.1	32.9	25.0	L
Bg2	84-104	2.5Y 4/2 & 4/4	few medium 10YR 5/8 mottles	7.2	0.2	1	46.9	31.4	21.7	L
Cg1	104-114	2.5Y 5/4	common fine 2.5Y 5/2 Fe depletns. common fine 10YR 5/8 mottles	8.0	-	8	48.2	34.1	17.7	L
Ckg1	114-142	2.5Y 5/6 & 4/4	few fine 2.5Y 5/2 Fe depletions few fine/medium 7.5YR 5/6 mottles	8.0	-	17	47.7	36.1	16.2	L
Ckg2	142-175	2.5Y 4/4	common medium 2.5Y 5/2 Fe depl. few fine/medium 7.5YR 5/6 mottles	8.3	-	18	46.6	37.3	16.1	L
Cg2	175-196	2.5Y 4/4	few fine 2.5Y 5/2 Fe depletions few fine 10YR 5/8 mottles	8.3	-	15	46.3	37.4	16.3	L
			Well 3: Delft loam-Upland Prairie-Shoulder-Backslope							
A1	0-18	2.5Y 2/0	-	5.5	6.1	-	33.3	43.5	23.2	L
A2	18-30	2.5Y 2/1	-	5.0	5.1	-	31.0	44.8	24.2	L
A3	30-58	2.5Y 2/1	few fine 2.5Y 3/2 mottles	5.8	3.4	-	31.0	40.7	28.3	CL
A4	58-76	2.5Y 3/0	common fine 2.5Y 3/2 mottles	6.1	1.7	-	35.1	36.4	28.5	CL
Bg1	76--86	2.5Y 3/1 & 4/2	few fine 10YR ¾ mottles	6.5	1.0	-	37.2	36.4	26.4	L
Bg2	86-107	2.5Y 4/2	few fine 10YR 5/8 mottles	7.1	0.4	1	40.2	35.5	24.3	L
Cg1	107-122	2.5Y 5/2	few fine 10YR 5/8 mottles	8.0	-	8	41.9	37.1	21.0	L
Cg2	122-135	2.5Y 5/2	few fine 10YR 5/8 mott.	8.0	-	10	47.0	33.9	19.1	L
Cg3	135-165	2.5Y 5/2	many fine 10YR 5/8 mottles Mn & 7.5YR 4/6 concretions	8.2	-	17	46.3	36.1	17.6	L
Cg4	165-183	2.5Y 5/2	few medium 10YR 5/6 & 5/8 mott.	8.2	-	16	42.9	40.8	16.3	L
			Well 4: Deft clay loam-Upland Prairie-Backslope							
A1	0-15	2.5Y 2/0	-	6.3	6.8	-	26.5	44.7	28.8	CL
A2	15-30	2.5Y 2/0	few fine 2.5Y 3/2 mottles	6.6	4.7	-	25.4	43.3	31.3	CL
A3	30-48	2.5Y 2/0	few fine 2.5Y 3/2 & 4/2 mottles	6.8	2.2	-	26.9	42.0	31.1	CL
A4	48-66	5Y 2/1	few medium 2.5Y 4/1 Fe mottles	6.8	1.1	-	25.6	42.6	31.8	CL
Bg	66-79	2.5Y 3/1	few fine 2.5Y 4/2 & 5/2 mottles	7.3	0.2	3	31.7	37.8	30.5	CL
2BCg	79-99	2.5Y 5/2	-	7.5	0.2	2	54.9	24.2	20.9	SaL
2Cg	99-112	2.5Y 5/2	common fine 10YR 5/8 mottles 7.5YR ¾ concretions	7.9	0.1	3	52.8	26.1	21.1	SaL
3Cg	112-137	2.5Y 5/2	few fine 2.5Y 4/4 & 10YR 5/8 mot	8.0	-	8	44.4	31.3	24.3	L
4Cg	137-191	2.5Y 5/2	common medium 2.5Y 4/4 mottles few fine 10YR 5/8 mottles	8.1	-	13	36.2	35.5	28.3	CL
5Cg	191-221	2.5Y 5/2	common medium 2.5Y 4/4 mottles	8.3	-	18	49.9	31.9	18.2	L

Table 20. Selected soil morphology and characterization data for Group III soils on transect 2 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Canisteo clay loam-Wet Prairie-Footslope							
A1	0-23	N 2/0	-	7.7	5.3	2	34.3	38.1	27.6	CL
A2	23-46	2.5Y 2/0	few medium 2.5Y 4/1 Fe depletions	7.8	1.1	2	26.9	45.0	28.1	CL
Bg1	46-53	2.5Y 5/2 & 4/2	few fine 10YR 4/6 mottles	8.0	0.3	3	45.1	30.5	24.4	L
Bg2	53-74	2.5Y 5/2	common fine 10YR 4/6 mottles	8.0	0.2	6	52.6	25.5	21.9	SaL
Bg3	74-86	2.5Y 5/2	few fine 10YR 4/6 mottles	8.1	-	8	39.8	37.7	22.5	L
Cg	86-107	2.5Y 5/1 & 3/1	few fine 2.5Y 4/4 mottles common fine 7.5YR 5/8 mottles Mn concretions	8.2	-	13	27.1	46.0	26.9	L
2Cg1	107-122	5Y 5/1	few fine 2.5Y 4/4 mottles	8.3	-	17	42.4	39.8	17.8	L
2Cg2	122-137	5Y 5/1	common fine 10YR 4/6 & 5/8 mottles	8.3	-	19	39.7	47.7	12.6	L
2Cg3	137-160	5Y 5/1	few medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles Mn concretions	8.3	-	18	35.4	52.0	12.6	L
2Cg4	160-175	5Y 5/1	few fine 2.5Y 4/4 mottles common fine 7.5YR 4/6 mottles Mn concretions	8.2	-	15	35.2	41.5	23.3	L
2Cg5	175-213	5Y 5/1 & 5/2	few fine 10YR 4/6 mottles Mn concretions	8.2	-	20	40.6	46.6	12.8	L

Table 21. Selected soil morphology and characterization data for Group IV soils on transect 2 in Colo Bog.

Horizon	Depth cm	Matrix Color*	Fe Concentration*	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture **
			Okoboji silty clay loam-Sedge Pond Depression-Toeslope							
A1	0-28	2.5Y 2/0	-	6.8	6.9	-	15.2	50.4	34.4	SiCL
A2	28-53	2.5Y 2/0	few fine and medium 2.5Y 3/2 mottles few fine 2.5Y 4/4 mottles	7.4	1.8	1	22.2	44.4	33.6	CL
A3	53-74	2.5Y 2/0	common fine 2.5Y 4/2 & 4/4 mottles few medium 5Y 5/2 Fe depletions	7.4	1.1	2	26.7	42.5	30.8	CL
Bg	74-91	5Y 5/1	few fine 2.5Y 5/6 mottles many fine 2.5Y 4/4 mottles	7.8	0.2	7	32.2	40.3	27.5	CL
BCg	91-112	5Y 5/1 & 4/1	few fine 10YR 4/6 & 2.5Y 4/4 mottles	8.0	-	14	39.8	38.0	22.2	L
2Cg1	112-140	5Y 4/1	common medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	8.2	-	18	53.7	31.5	14.8	SaL
2Cg2	140-155	5Y 5/1	many medium 2.5Y 4/4 mottles Mn and 7.5YR 4/6 concretions	8.2	-	18 19	51.4	32.9	15.7	L
2Cg3	155-168	2.5Y 4/4 & 5/4	Few fine 5Y 5/2 Fe depletions 7.5YR 4/6 concretions	8.2	-	11	54.7	33.5	11.8	SaL
3Cg	168-198	2.5Y 4/2, 4/4, 3/2	few medium 5Y 5/1 Fe depletions 10YR 3/6 fracture linings	8.0	-		42.6	36.1	21.3	L

Table 22. Selected soil morphology and characterization data for Group I soils on transect 3 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Nicollet loam Taxadjunct-Upland Prairie-Summit							
A1	0-18	10YR 2/1	-	5.7	4.3	-	40.3	37.5	22.2	L
A2	18-33	10YR 3/1	-	5.8	2.9	-	42.4	39.0	18.6	L
A3	33-53	10YR 3/1	few fine 10YR 3/2 mottles	6.0	1.9	-	44.7	33.6	21.7	L
ABg	53-64	10YR 3/1	few fine 2/5Y 4/4 mottles common fine 2.5Y 4/2 mottles	6.7	1.2	-	49.0	29.8	21.2	L
Bg	64-81	2.5Y 4/2	few fine 2.5Y 4/4 & 4/6 mottles	7.9	-	25	55.2	26.6	18.2	SaL
Bkg	81-99	5Y 5/2	few fine 2.5Y 4/4 & 10YR 4/6 mottles Mn concretions	8.2	-	18	55.0	30.1	14.9	SaL
Ckg	99-117	5Y 5/2	common fine 2.5Y 4/4 mottles few fine 10YR 4/6 mottles Mn and 5YR 4/6 concretions	8.2	-	19	50.5	33.1	16.4	L
Cg1	117-145	2.5Y 4/4	few fine 5Y 5/2 Fe depletions few fine 10YR 5/4 mottles 5YR 4/6 concretions	8.3	-	20	52.6	35.3	12.1	SaL
Cg2	145-226	2.5Y 4/4	few fie 5Y 5/2 Fe depletions few fine 10YR 5/4 mottles Mn concretions	8.3	-	17	54.1	32.2	13.7	SaL

Table 23. Selected soil morphology and characterization data for Group II soils on transect 3 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Nicollet loam-Upland Prairie-Backslope							
A1	0-23	N 2/0	-	6.0	4.5	-	37.8	38.7	23.5	L
A2	23-38	N 3/0	common fine 2.5Y 3/2 mottles	6.8	2.2	-	41.4	35.4	23.2	L
Bw	38-56	2.5Y 4/2	-	7.5	0.4	2	42.7	36.3	21.0	L
Bg1	56-74	2.5Y 4/2 & 5Y 4/1	few fine 2.5Y 4/4 mottles	7.9	0.2	8	42.9	38.6	18.5	L
Bg2	74-89	5Y 4/1 & 6/2	few fine 2.5Y 5/4 mottles	8.2	-	13	45.9	37.4	16.7	L
BCg	89-107	5Y 6/2	few fine 10YR 5/4 & 5/6 mottles	8.3	-	18	43.4	42.4	14.2	L
Ckg	107-117	5Y 6/2	few fine 10YR 5/6, 2.5Y 4/4 mottles common Mn concretion	8.3	-	20	42.5	44.1	13.4	L
Cg1	117-127	5Y 6/2	common f/m 2.5Y 4/4 mottles few fine 10YR 4/6 mottles Mn concretions	8.3	-	18	40.3	48.4	11.3	L
Cg2	127-160	2.5Y 4/4	few fine 10YR 4/6 mottles few fine 5Y 5/1 Fe depletions Mn concretions	8.3	-	17	44.5	45.1	10.4	L
Cg3	160-224	5Y 5/1 & 2.5Y 5/2	many fine/medium 2.5Y 4/4 mottles Mn and 7.5YR ¾ & 4/6 concretions	8.2	-	17	49.2	36.4	14.4	L
			Well 3: Delft clay loam-Upland Prairie-Backslope							
A1	0-18	N 2/0	-	5.9	6.6	-	25.4	46.2	28.4	CL
A2	18-36	N 2/0	-	6.2	5.2	-	21.8	46.5	31.7	CL
A3	36-56	N 2/0	few fine 2.5Y 3/2 mottles	6.6	2.6	-	18.7	46.5	34.8	CL
A4	56-74	N 3/0	few fine/medium 2.5Y 3/2 mottles	6.8	1.7	-	20.5	44.4	35.1	CL
Bg1	74-89	5Y 3/1	few fine 5Y 5/2 Fe depletions	6.9	0.9	-	18.2	49.8	32.0	CL
Bg2	89-104	5Y 6/2 & 4/1	-	7.2	0.2	2	22.3	50.3	27.4	SiCL
BCg	104-122	5Y 6/2 & 4/1	common fine 10YR 4/6 mottles few fine 2.5Y 4/4 mottles	7.9	0.1	5	46.9	32.2	20.9	L
Cg1	122-135	5Y 5/1	few fine 2.5Y 4/4, 10YR 4/6 mottles	7.7	-	7	34.0	39.9	26.1	L
Cg2	135-157	5Y 4/1	common fine 10YR 4/6 mottles few fine 2.5Y 4/4, 10YR 5/8 mottles	7.8	-	9	36.5	38.0	25.5	L
Ckg	157-203	5Y 4/1, 5/1, 4/3	common fine 10YR 4/6 mottles few fine/medium 10YR 5/8 mottles	8.0	-	11	45.5	32.9	21.6	L

Table 24. Selected soil morphology and characterization data for Group III soils on transect 3 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Delft-Canisteo loam-Wet Prairie I-Footslope							
A1	0-23	N 2/0	few 10YR ¾ pore linings	7.7	4.3	10	29.7	43.5	26.8	L
A2	23-41	2.5Y 2/0	few fine 2.5Y 4/2 & 5/2 mottles	7.8	3.3	3	25.9	42.7	31.4	CL
A3	41-53	N 3/0	few fine 2.5Y 3/2 mottles	7.9	1.8	2	23.0	44.6	32.4	CL
A4	53-71	10YR 3/1	few fine 2.5Y 4/4 & 5Y 4/3 mottles	7.8	1.2	3	25.8	42.5	31.7	CL
ABg	71-89	N 2/0 & 10YR 3/1	few fine 2.5Y 4/2 mottles	7.7	0.9	3	27.7	41.8	30.5	CL
Bg	89-104	5Y 4/1 & 6/2	-	8.1	0.7	9	34.3	38.5	27.2	CL
Ckg1	104-132	5Y 4/1 & 6/2	few fine 10YR 4/6 & 2.5Y 5/4 mott. Mn concretions	8.2	-	16	44.5	32.2	23.3	L
Cg	132-155	5Y 4/1	common f/m 10YR 4/6 mottles few fine 10YR 5/8 & 2.5Y 4/4 mott.	8.2	-	27	45.4	34.3	20.3	L
Ckg2	155-175	5Y 4/1	many fine 10YR 4/6 mottles common fine 7.5YR ¾ mottles few fine 2.5Y 4/4 mottles	8.2	-	16	46.7	32.5	20.8	L
2Cg	175-203	5Y 4/1,5/1, 4/4	few fine 10YR 4/6 mottles	8.2	-	16	33.5	27.5	39.0	CL
			Canisteo clay loam-Wet Prairie II-Footslope							
A1	0-23	N 2/0	-	7.9	5.8	11	28.5	41.6	29.9	CL
A2	23-38	N 2/0	-	8.1	3.4	15	23.2	44.8	32.0	CL
A3	38-48	10YR 3/1	few fine 2.5Y 4/4 & 4/2 mottles	8.2	1.2	10	22.5	46.5	31.0	CL
Bg1	48-61	5Y 4/1	few fine 5Y 5/2 Fe depletions	8.2	1.1	11	23.9	46.4	29.7	CL
Bg2	61-76	5Y 6/2 & 3/1	few fine 2.5Y 4/4 mottles	8.3	0.3	16	25.2	47.0	27.8	CL
Bg3	76-94	5Y 6/2 & 3/1	few f. 7.5YR 4/6, 2.5Y 5/4, 4/4 mo.	8.3	-	18	36.7	39.4	23.9	L
Cg	94-130	5Y 6/2	few fine/medium 7.5YR 4/6 mottles few fine 2.5Y 4/4 mottles Mn concretions	8.3	-	18	41.6	36.1	22.3	L
2Cg1	130-145	5Y 4/1	many fine 10YR 4/6 mottles Mn concretions	8.1	-	16	33.4	38.0	28.6	CL
2Cg2	145-157	2.5Y 4/2, 5Y 4/1	few fine 2.5Y 4/4 mottles	8.2	-	16	36.6	37.1	26.3	L
			Canisteo loam-Wet Prairie III-Footslope							
A1	0-13	N 2/0	-	7.6	5.1	3	46.6	34.5	18.9	L
A2	13-25	N 2/0	-	7.7	4.3	3	42.0	37.6	20.4	L
A3	25-41	2.5Y 3/1	few fine 2.5Y 4/2 & 5/2 Fe dep.	7.8	1.8	5	46.6	31.8	21.6	L
Bg1	41-53	5Y 3/1 & 2.5Y 4/2	few fine 10YR 4/6 mottles few fine 2.5Y 5/2 Fe depletions	8.0	0.6	6	50.7	30.2	19.1	L
Bg2	53-64	5Y 6/2, 5/2, 4/2	few fine 10YR 4/6 mottles	8.1	0.1	9	65.3	21.8	12.9	SaL
Cg1	64-76	5Y 6/2, 5/1, 5/2	many fine 2.5Y 4/4 mottles	8.3	-	11	75.9	15.8	8.3	LS
			few fine 10YR 4/6 mottles		-				5.2	
Cg2	76-137	5Y 6/1 & 5/1	few fine 2.5Y 4/4, 10YR 4/6, ¾ mo. Mn concretions	8.4		10	83.9	10.9		LS

Table 25. Selected soil morphology and characterization data for Group IV soils on transect 3 in Colo Bog.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Glencoe loam-Cattail Pond Depression-Toeslope							
A1	0-13	N 2/0	-	7.6	5.7	3	37.1	39.0	23.9	L
A2	13-46	N 2/0	few fine 10YR 4/6 mottles	7.3	3.9	2	31.4	42.4	26.2	L
ABg	46-61	N 3/0 & 5Y 3/1	few fine 10YR 4/6 mottles	7.4	1.0	1	31.5	40.9	27.6	CL
Bg1	61-74	N 3/0	few fine 2.5Y 5/2 Fe depletions	7.6	0.8	2	33.4	38.7	27.9	CL
Bg2	74-94	5Y 5/2 & 4/1	few fine 10YR 4/6 mottles	7.7	0.4	1	37.4	35.0	27.6	CL
BCg	94-122	5Y 5/2 & 4/1	few fine 10YR 4/6 & 5/6 mottles 10YR 4/6 Fe concretions	7.9	0.2	2	46.4	32.4	21.2	L
Cg	122-165	5Y 5/2 & 4/1	common fine 10YR 4/6 mottles few fine 10YR 5/6, 7.5YR 4/6, ¾ mott. Mn concretions	8.1	-	11	42.4	38.9	18.7	L

Table 26. Selected soil morphology and characterization data for Group I soils on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 1: Clarion loam-Upland Prairie-Summit							
A1	0-13	10YR 2/1	-	7.5	4.6	20	35.6	41.0	23.4	L
A2	13-30	10YR 2/1	-	6.3	4.1	-	30.9	42.0	26.9	L
A3	30-43	10YR 2/1	-	6.8	3.3	-	28.1	44.0	27.9	CL
Bw	43-61	10YR 3/3	-	7.4	1.0	3	32.9	41.0	26.1	L
BCg	61-76	2.5Y 4/4	few fine 2.5Y 4/2 Fe depletions	7.9	0.2	13	51.1	28.9	20.0	L
			few fine/medium 7.5YR ¾ mottles							
Ckg1	76-114	2.5Y 5/2	common medium 2.5Y 4/4 mottles	8.5	-	20	51.4	32.2	16.4	L
			few fine 10YR 4/6 mottles							
			few fine 7.5YR ¾ concretions							
Ckg2	114-173	2.5Y 6/2	few fine 10YR 4/6 mottles	8.6	-	21	49.9	34.0	16.1	L
			many medium 2.5Y 5/4 mottles.							
			7.5YR ¾ and Mn concretions							
Cg	173-244	2.5Y 6/2	many f/m 2.5Y 5/4 & 4/4 mottles	8.4	-	18	51.2	33.2	15.6	L
			7.5YR ¾ concretions							
			Well 2: Clarion loam-Upland Prairie-Shoulder Slope							
A1	0-23	10YR 2/1	-	6.3	3.6	-	41.7		22.7	L
A2	23-43	10YR 3/1	-	6.2	2.6	-	34.5		27.8	CL
Bw	43-61	10YR 4/3	-	7.0	1.0	3	45.6		24.5	L
BCg	61-74	2.5Y 4/4	few fine 2/5Y 4/2 Fe depletions	7.5	0.9	17	52.6		19.0	SaL
			few fine 10YR 4/6 mottles							
Cg	74-84	2.5Y 5/2	few fin. 10YR 4/6, 5/6, 2.5Y 5/4 mo	8.0	-	14	52.4		16.2	SaL
Ckg1	84-114	2.5Y 5/2	common fine 2.5Y 4/4 & 5/4 mott.	8.2	-	23	48.5		17.0	L
			few fine 10YR 4/6 mottles							
			7.5YR ¾ concretions							
Ckg2	114-137	2.5Y 5/2	common fine 2.5Y 5/4 mottles	8.2	-	18	48.9		16.4	L
			few fine 10YR 4/6 mottles							
			7.5YR ¾ concretions							
Ckg3	137-203	2.5Y 5/2 & 6/2	many fine/medium 2.5Y 5/4 mottles	8.3	-	24	51.6		15.5	L
			common medium 10YR 4/6 mottles							
			7.5YR ¾ & Mn concretions							

Table 27. Selected soil morphology and characterization data for Group II soils on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Feature	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Webster loam-Upland Prairie-Backslope							
A1	0-15	2.5Y 2/1	-	5.8	4.3	-	42.3	36.3	21.4	L
A2	15-33	2.5Y 2/1	few fine 2.5Y 3/2 mott.	6.0	3.6	-	37.3	37.8	24.9	L
A3	33-48	2.5Y 3/1	few fine 2.5Y 3/2 mott.	6.5	2.2	-	38.2	36.7	25.1	L
Bg	48-64	2.5Y 4/2	few fine 2.5Y 4/4 mottles 10YR 4/6 concretions	7.4	0.5	7	41.7	35.4	22.9	L
BCg	64-79	2.5Y 4/2	common fine 2.5Y 4/4 few fine 10YR 4/6 mottles	7.8	-	22	48.7	34.9	16.4	L
Cg1	79-107	2.5Y 5/2, 5Y 4/1	common fine 2.5Y 5/4 mottles few fine 10YR 4/6 mottles few 7.5YR ¾ concretions	8.2	-	20	50.8	32.7	16.5	L
Ckg1	107-122	2.5Y 5/2, 5Y 5/1	few fine/medium 2.5Y 5/4 mottles few fine 10YR 4/6 mottles	8.2	-	24	48.7	34.1	17.2	L
Ckg2	122-175	2.5Y 5/2, 5Y 5/1	common f/m 2.5Y 5/4 mott.	8.2	-	26	50.4	33.8	15.8	L
Cg	175-218	5Y 5/1	many f/m 2.5Y 5/4 & 4/4 mott. 7.5YR 5/8 concretions	8.2	-	22	51.5	32.9	15.6	L

Table 28. Selected soil morphology and characterization data for Group III soils on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Feature	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 4: Canisteo clay loam-Wetland Zone 1-Footslope							
A1	0-18	N 2/0	-	7.9	5.6	8	31.1	39.4	29.5	CL
A2	18-33	N 2/0	few f/m 2.5Y 4/2 & 5/2 Fe dep.	8.1	3.2	14	31.1	39.9	29.0	CL
A3	33-53	N 2/0	few fine 2.5Y 3/2 and 4/2 Fe dep.	8.2	2.7	8	28.9	41.1	29.7	CL
Bg1	53-66	N 3/0 & 5Y 4/1	-	8.2	0.7	18	29.6	41.8	28.6	CL
Bg2	66-81	5Y 4/1 & N 3/0	few fine 10YR 4/6 & 2.5Y 5/6 mott.	8.3	0.4	19	40.1	36.0	23.9	L
Cg	81-109	5Y 5/1 & 5/2	many fine 10YR 4/6 mottles	8.3	-	21	46.7	32.8	20.5	L
2Cg1	109-135	5Y 5/1 & 4/1	few fine 2.5Y 5/6 and 4/6 mottles	8.1	-	8	35.3	37.6	27.1	CL
2Cg2	135-173	5Y 5/1 & 4/1	common f/m 2.5Y 5/6 & 4/6 mottles	8.3	-	19	38.7	37.0	24.3	L
3Cg	173-218	2.5Y 5/4 & 4/4	few f/m 5Y 4/1 & 5/1 Fe dep.	8.3	-	18	48.8	33.3	17.9	L
			Well 5: Canisteo clay loam-Cattail Zone-Footslope							
A1	0-10	N 2/0	-	7.5	6.2	4	28.8	43.0	28.2	CL
A2	10-23	N 2/0	-	7.7	5.6	4	27.8	42.3	29.9	CL
A3	23-41	N 3/0	-	7.8	1.8	3	32.0	38.0	30.0	CL
A4	41-56	N 3/0 & 10YR 3/1	-	7.7	1.0	5	34.5	37.5	28.0	CL
Bg	56-71	10YR 3/1 & 5Y 5/2	-	8.0	0.8	6	40.4	35.5	24.1	L
Bkg	71-84	5Y 4/1 & 5Y 5/2	few coarse 10YR 4/6 mottles	8.0	-	16	47.3	32.5	20.2	L
Ckg	84-114	5Y 4/1 & 5/1	few f/m 10YR 4/6 mottles	8.1	-	15	46.3	33.4	20.3	L
Cg1	114-157	5Y 4/1 & 5/1	com. f/m 10YR 4/6, 2.5Y 4/4 mot. Mn concretions	8.3	-	20	49.8	33.4	16.8	L
Cg2	157-221	2.5Y 4/4 & 5/4	few fine 5Y 5/1 & 4/1 Fe depletions. Mn concretions	8.2	-	29	49.5	33.2	17.3	L

Table 29. Selected soil morphology and characterization data for Group IV soils on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 6: Canisteo clay loam-Pond Depression-Toeslope							
A1	0-15	N 2/0	-	7.3	5.6	5	22.7	44.0	33.3	CL
A2	15-36	N 2/0	few fine 5Y 4/3 mottles	7.5	2.5	5	28.7	39.0	32.3	CL
A3	36-53	N 2/0	few f/m 5Y 4/3 mottles	7.5	1.3	3	35.5	33.3	31.2	CL
Bg	53-71	N 3/0 & 5Y 4/1	-	7.6	0.6	5	31.9	36.5	31.6	CL
BCg	71-89	5Y 4/1 & 5/2	common fine 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	7.9	-	12	46.4	30.7	22.9	L
Cg1	89-135	5Y 4/1 & 5/2	common fine 2.5Y 4/4, 10YR 4/6 mott. few 5YR 4/6 concretions	8.1	-	18	49.7	31.5	18.8	L
Cg2	135-155	5Y 4/1, 3/1,5/2	few medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles Mn concretions	8.0	-	10	45.1	30.7	24.2	L
Cg3	155-178	5Y 4/1 & 5/1	common coarse 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	8.2	-	20	51.1	31.0	17.9	L
Cg4	178-208	2.5Y 4/4 and 5/4	few fine 5Y 4/1 Fe depletions few fine 10YR 4/6 mottles Mn concretions	8.2	-	25	51.8	31.1	17.1	L
			Well 7: Okoboji silty clay loam- Pond Depression-Toeslope							
A1	0-15	N 2/0	-	6.5	7.3	-	9.6	52.8	37.6	SiCL
A2	15-36	N 2/0	-	6.8	5.4	-	11.6	51.7	36.7	SiCL
A3	36-61	N 2/0	few fine 5Y 4/3 mottles	7.0	2.8	-	6.5	54.3	39.2	SiCL
A4	61-84	N 2/0	few fine 2.5Y 4/2 mottles	7.2	2.0	4	6.7	52.1	41.2	SiC
AB	84-104	N 2/0, 10YR 3/1	common fine 2.5Y 4/2 mottles	7.6	1.2	4	5.7	55.1	39.2	SiCL
Cg1	104-122	5Y 5/2 & 5/1	common fine 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	7.6	-	5	8.9	68.0	23.1	SiL
Cg2	122-157	5Y 5/1 & 4/1	common fine 2.5Y 4/4, 10YR 4/6 mott.	7.9	-	24	6.4	77.9	15.7	SiL
Cg3	157-208	5Y 4/1	common med 2.5Y 4/4, 10YR 4/6 mott.	7.9	-	19	8.3	71.5	20.2	SiL

Table 30. Selected soil morphology and characterization data for Group I soils on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 1: Crippin loam-Upland Prairie-Shoulder-Backslope							
A1	0-10	10YR 2/1	-	7.5	4.2	4	48.6	30.8	20.6	L
A2	10-30	10YR 2/1	few fine 10YR 5/4 mottles	8.0	4.2	21	46.6	30.2	23.2	L
BA	30-53	10YR 3/1	few fine 2.5Y 4/2 mottles	8.3	1.4	16	45.1	33.1	21.8	L
Bkg	53-79	2.5Y 4/2	many f/m 2.5Y 5/6 & 5/4 & 4/4 mot common medium 10YR 5/4 mottles few fine 2.5Y 4/4 mottles	8.4	-	30	46.3	36.4	17.3	L
BCkg	79-102	2.5Y 6/2	7.5YR 4/6 concretions few f/m 10YR 5/4 mottles few fine 2.5Y 4/4 mottles	8.5	-	22	50.1	33.6	16.3	L
Ckg	102-140	2.5Y 6/2	7.5YR 4/6 concretions few f/m 2.5Y 5/4 mottles common fine 10YR 4/6 mottles	8.4	-	30	49.4	34.6	16.0	L
Cg	140-213	2.5Y 6/2	7.5YR 5/8 concretions many f/m 2.5Y 5/4 mottles few m/c 10YR 4/6 mottles Mn concretions	8.4	-	22	49.6	35.4	15.0	L

Table 31. Selected soil morphology and characterization data for Group II soils on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 2: Canisteo loam-Upland Prairie-Backslope							
A1	0-15	N 2/0	-	7.9	6.3	7	43.7	35.9	20.4	L
A2	15-28	N 2/0	-	7.7	6.0	19	41.0	36.5	22.5	L
A3	28-48	N 2/0	-	7.7	2.6	19	37.6	36.9	25.5	L
Bg	48-79	N 3/0	few fine 5Y 4/2 mottles	7.8	1.0	13	35.3	39.1	25.6	L
			common fine 5Y 5/2 mottles							
2Ckg	79-99	5Y 5/2	few fine 2.5Y 5/4 mottles	8.4	-	14	59.8	26.2	14.0	SaL
2Cg	99-127	5Y 6/2	few fine 2.5Y 5/4 mottles	8.3	-	21	55.4	29.9	14.7	SaL
			common m/c 10YR 4/6 mottles		-					
3Cg1	127-150	5Y 4/1	many f/m 10YR 4/6 & 2.5Y 4/4 mo	8.2	-	16	47.7	33.0	19.3	L
3Cg2	150-213	2.5Y 4/2	few f 10YR 4/6, 2.5Y 5/4 & 4/4 mo	8.2		22	43.8	36.1	20.1	L

Table 32. Selected soil morphology and characterization data for Group III soils on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Fe Concentration	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Canisteo loam-Wetland Zone 1-Footslope							
A1	0-15	N 2/0	-	7.5	7.1	3	37.7	40.9	21.4	L
A2	15-33	N 2/0	-	7.6	5.1	17	34.2	43.1	22.7	L
A3	33-53	N 3/0	-	7.8	1.6	17	40.2	38.5	21.3	L
AB	53-71	N 3/0	few fine 5Y 5/2 & 4/3 mottles	7.7	1.2	19	27.9	45.6	26.5	L
			7.5YR 3/3 pore linings							
Bg	71-91	N 3/0 & 5Y 3/1	few m/c 5Y 5/2 mottles	7.8	0.7	17	14.7	54.7	30.6	SiCL
			7.5YR 3/3 pore linings							
2Cg1	91-102	5Y 4/1 & 5/2	common fine 4/4 mottles	8.1	-	17	31.4	46.1	22.5	L
			7.5YR 3/3 & 4/6 pore linings							
2Cg2	102-119	5Y 5/1	many fine 2.5Y 4/4 mottles	7.9	-	11	28.3	51.8	19.9	SiL
			7.5YR 4/6 pore linings							
2Cg3	119-142	5Y 5/1	many fine 10YR 3/3 mottles	8.0	-	15	32.1	48.5	19.4	L
			common fine 10YR 4/6 & 2.5Y 4/4 mo							
			7.5YR 4/6 pore linings							
3Cg1	142-152	5Y 5/1 & N 3/0	common fine 10YR 3/3 mottles	8.1	-	18	40.2	41.2	18.6	L
			few fine 2.5Y 4/4 mottles							
			7.5YR 4/6 pore linings							
3Cg2	152-173	5Y 5/1	many fine 2.5Y 4/4 & 10YR 4/6 mott.	8.1	-	20	36.1	45.3	18.6	L
			few fine 7.5YR 4/6 mottles			20				
4Cg	173-196	5Y 5/1	many fine 2.5Y 4/4 mottles	8.1	-		20.0	60.9	19.1	SiL
			common fine 10YR 4/6 mottles							
			few fine 7.5YR 4/6 mottles							
			Well 4: Canisteo silt loam-Cattail Zone-Footslope							
A1	0-15	N 2/0	-	7.2	9.8	3	17.8	57.6	24.6	SiL
A2	15-41	N 2/0	-	7.4	5.3	11	20.5	55.9	23.6	SiL
A3	41-58	N 3/0	few fine 2.5Y 4/2 mottles	7.7	1.8	2	10.9	58.3	30.8	SiCL
Bg1	58-69	N 3/0	few fine 5Y 5/2 mottles	7.8	0.6	4	6.6	60.9	32.5	SiCL
			7.5YR 3/3 pore linings							
Bg2	69-84	5Y 4/1 & N 3/0	few fine 5Y 5/2 mottles	7.9	0.1	3	1.9	62.9	35.2	SiCL
			7.5YR 3/3 pore linings							
Cg1	84-112	5Y 4/1& 5/2	many fine 2.5Y 4/4 mottles	7.9	-	18	15.2	60.9	23.9	SiL
			7.5YR 3/3 pore linings							
Cg2	112-135	5Y 5/1	common fine 2.5Y 4/4 mottles	7.9	-	16	26.3	54.4	19.3	SiL
			few fine 10YR 4/6 mottles							
Cg3	135-157	5Y 5/1	many fine 10YR 4/6 mottles	8.0	-	23	21.5	61.1	17.4	SiL
			common fine 2.5Y 4/4 mottles							
Cg4	157-170	5Y 5/1 & N 3/0	few fine 10YR 3/3 mottles	8.1	-	17	13.4	63.8	22.8	SiL
			common fine 10YR 4/6, 2.5Y 4/4 mott.							
2Cg	170-183	5Y 5/1, 4/1, 5/2	few fine 10YR 4/6 & 2.5Y 4/4 mottles	8.2	-	23	44.4	41.3	14.3	L
3Cg	183-213	5Y 5/1 & 4/1	few medium 2.5Y 4/4 mottles	8.2	-	30	28.9	52.9	18.2	SiL
			many fine 10YR ¾ mottles							

Table 32. (continued).

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 6: Harps loam-Cattail Zone-Toeslope							
A	0-23	N 2/0	-	7.5	7.5	3	40.5	40.8	18.7	L
AB	23-51	N 3/0, 5Y 4/1, 6/2	10YR ¾ pore linings	8.2	4.7	27	39.0	39.1	21.9	L
2Bg	51-76	5Y 6/2	many coarse 10YR 5/6 mottles 7.5YR 4/6 pore lining	8.2	-	32	14.5	67.2	18.3	SiL
2BCg	76-94	5Y 5/1	few fine 2.5Y 5/4 & medium 4/6 mottles	8.2	-	45	6.4	80.3	13.3	SiL
2Cg	94-122	5Y 5/1	many medium 10YR 5/6 mottles 7.5YR 4/6 pore linings	8.2	-	24	2.1	78.6	19.3	SiL
3Cg	122-145	5Y 5/1	common coarse 2.5Y 5/4, med 4/4 mott. few medium 10YR 5/6 mottles	8.2	-	28	25.4	58.3	16.3	SiL
4Cg	145-165	5Y 5/4, 4/4, 5/1	few coarse 10YR 5/6 mottles	8.3	-	22	36.2	50.8	13.0	SiL
5Cg	165-201	5Y 5/1	few medium 2.5Y 5/4 & 4/4 mottles	8.1	-	21	43.4	43.7	12.9	L
			Well 7: Canisteo loam-Cattail Zone-Toeslope							
A1	0-25	N 2/0	-	7.1	8.0	3	41.1	40.3	18.6	L
A2	25-51	N 2/0, 10YR 3/1	10YR ¾ pore linings few fine 5Y 5/1 Fe depletions	7.9	1.5	15	55.3	29.6	15.1	SaL
Bg	51-86	5Y 6/2	common fine 10YR 5/6 mottles 7.5YR 4/6 pore linings	7.9	0.3	19	31.1	52.2	16.7	SiL
2Cg	86-104	5Y 5/1	common fine 2.5Y 4/4 mottles few medium 10YR ¾ mottles 7.5YR 4/6 pore linings	8.2	-	19	62.2	22.8	15.0	SaL
3Cg	104-117	5Y 5/1	many medium 10YR 5/6 & 5/8 mottles common fine 2.5Y 4/4 mottles	8.0	-	20	35.1	41.1	23.8	L
4Cg1	117-132	2.5Y 4/2, 5Y 5/1	common fine 2.5Y 4/4 mottles few medium 2.5 5/4 mottles few fine 7.5YR 4/6, 10YR 5/6 mottles	8.0	-	24	49.3	34.4	16.3	L
4Cg2	132-150	5Y 5/1	common medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	8.1	-	19	45.9	36.5	17.6	L
5Cg	150-203	2.5Y 4/2	few medium 5Y 4/1 Fe depletions few fine 7.5YR ¾ mottles	8.1	-	22	55.4	30.4	14.2	SaL

Table 33. Selected soil morphology and characterization data for Group IV soils on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
Well 5: Okoboji silty clay loam-Pond Depression-Toeslope										
A1	0-18	N 2/0	-	7.2	11.0	3	16.0	55.3	28.7	SiCL
A2	18-43	N 3/0	-	7.0	5.5	16	12.0	58.5	29.5	SiCL
A3	43-61	N 3/0	few fine 5Y 5/2 & 4/3 mottles 7.5YR 4/6 pore linings	7.4	1.9	15	13.5	54.0	32.5	SiCL
AB	61-71	N 3/0, 5Y 5/1	common fine 10YR 4/6 & 3/6 mottles	7.6	1.8	16	3.4	61.7	34.9	SiCL
Bg	71-89	5Y 5/1	few f/m 10YR 4/6 mottles common fine 2.5Y 4/3 & 5/4 mottles few fine 7.5YR 3/3 mottles	7.8	0.1	7	6.4	62.3	31.3	SiCL
Ckg1	89-102	5Y 4/3	few fine 5Y 5/1 & 4/1 Fe depletions few fine 10YR 5/6 mottles	8.0	-	19	11.0	63.3	25.7	SiL
Ckg2	102-122	5Y 4/3	few fine 5Y 5/1 & 4/1 Fe depletions few fine 10YR 4/6 mottles	8.0	-	20	11.1	62.9	26.0	SiL
Ckg3	122-140	5Y 5/1	few fine 10YR 3/6 mottles few f/m 10YR 4/6, 5/6 & 5/8 mottles common fine 5Y 4/3 mottles few medium 2.5Y 4/4 mottles	8.1	-	26	11.0	64.4	24.6	SiL
2Cg1	140-150	5Y 5/1, 2.5Y 4/4	-	8.5	-	13	74.5	19.3	6.2	LS
2Cg2	150-183	5Y 4/3, 5/4, 5/1	few fine 10YR 3/6 & 4/6 mottles	8.5	-	20	79.3	15.6	5.1	LS

Table 34. Selected soil morphology and characterization data for Group I soils on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 1: Clarion loam-Upland Prairie-Summit							
A1	0-15	10YR 2/2	-	5.1	3.5	-	37.6	38.7	23.7	L
A2	15-30	10YR 2/2	-	5.3	3.3	-	34.7	39.6	25.7	L
A3	30-53	10YR 3/1	-	5.9	2.8	-	33.3	37.8	28.9	CL
Bw1	53-74	10YR 3/3	-	5.9	1.9	-	36.1	35.6	28.3	CL
Bw2	74-91	10YR 4/3	-	6.1	0.9	-	44.4	29.8	25.8	L
BCg	91-112	'2.5Y 4/2	few fine 7.5YR ¾ mottles	7.8	-	5	44.6	33.4	22.0	L
2Cg	112-150	10YR 4/3	few fine 7.5YR ¾ mottles	8.4	-	27	76.8	16.0	7.2	LS
3Ckg	150-188	10YR 4/3 2.5Y 5/4	few fine 7.5YR ¾ mottles few coarse 2.5Y 6/2 Fe depletions	8.3	-	29	42.8	42.1	15.1	L
4Cg	188-200	2.5Y 5/4	few coarse 2.5Y 6/2 Fe depletions	8.2	-	27	10.6	75.3	14.1	SiL
			Well 2: Clarion loam-Upland Prairie-Shoulder Slope							
A1	0-20	10YR 2/1	-	6.1	2.8	-	47.0	30.3	22.7	L
A2	20-36	10YR 3/3	-	6.7	1.3	-	46.0	27.8	26.2	L
Bw	39-48	10YR 4/4	-	7.1	0.3	3	47.0	31.0	22.0	L
Bk	48-61	2.5Y 5/4	-	8.2	-	25	45.8	37.1	17.1	L
2C	61-71	2.5Y 5/4	-	8.2	-	9	60.2	31.5	8.3	SaL
3Cg1	71-99	2/5Y 5/4	few f. 7.5YR 4/6 & 10YR 5/6 mott. few f/m 2.5Y 6/2 Fe depletions	8.3	-	22	50.0	35.1	14.9	L
3Ckg1	99-122	2.5Y 4/4	few f. 7.5YR 4/6 & 10YR 5/6 mott. few fine 2.5Y 6/2 Fe depletions	8.3	-	42	47.9	36.8	15.3	L
3Cg2	122-135	2.5Y 5/6	few coarse 2.5Y 6/3 Fe depletions few fine 10YR 4/6 mottles 7.5YR 5/8 concretions	8.2	-	21	48.8	34.6	16.6	L
3Cg3	135-152	2.5Y 5/4	many med. 2.5Y 6/2 & 5/2 Fe dep. many fine 10YR 4/6 mottles few fine 7.5YR 5/8 mottles	8.2	-	16	47.2	36.4	16.4	L
3Ckg2	152-180	2.5Y 5/4	few fine 2.5Y 6/2 Fe depletions few f. 10YR 4/6 & 7.5YR 4/6 mott.	8.4	-	22	48.8	35.2	16.0	L
3Cg4	180-203	2.5Y 5/4	common m/c 2.5Y 6/2 Fe depletions com. f. 10YR 4/6, few f 7.5YR 4/6 7.5YR 4/6 concretions	8.4	-	18	48.3	35.9	15.8	L

Table 35. Selected soil morphology and characterization data for Group II soils on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Delft loam-Upland Prairie-Backslope							
A1	0-23	7.5YR 2/0	-	5.9	5.0	-	36.0	42.4	21.6	L
A2	23-48	7.5YR 2/0	-	6.4	4.3	-	31.3	42.6	26.1	L
A3	48-61	2.5Y 2/1	few fine 10YR 3/2 mottles	6.4	2.9	-	31.6	41.2	27.2	CL
A4	61-81	2.5Y 3/1	few fine 2.5Y 3/2 mottles	6.6	2.0	-	37.5	38.0	24.5	L
Bg2	81-97	2/5Y 3/1	few fine 2.5Y 4/4 & 10YR 4/6 mottles	7.2	1.0	12	40.7	36.1	23.2	L
2Cg	97-122	2/5Y 4/2	few fine 2.5Y 4/4 & 10YR 4/6 mottles 7.5YR 4/6 & ¾ concretions	7.9	-	19	56.1	26.8	17.1	L
2Ckg1	122-142	2.5Y 6/2	few fine 2.5Y 5/6, 4/4, 10YR 4/6 mott. Mn concretions	8.3	-	19	53.7	30.6	15.7	L
2Ckg2	142-178	2.5Y 5/2	few fine 7.5YR 5/8 & 10YR 4/6 mott. common fine 2.5Y 5/4 mottles	8.4	-	23	51.3	33.0	15.7	L
2Cg	178-244	2/5Y 5/4	few medium 2.5Y 6/2 Fe depletions 7.5YR 5/8 concretions	8.4	-	19	53.6	28.5	17.9	L
			Well 4: Canisteo clay loam-Upland Prairie-Footslope							
A1	0-25	2.5Y 2/0	-	7.9	4.5	12	30.8	38.8	30.4	CL
A2	25-56	2.5Y 2/0	-	7.9	3.0	18	26.1	42.9	31.0	CL
Bg	56-81	N 3/0	-	7.9	1.1	4	31.9	38.5	29.6	CL
Bkg	81-99	5Y 3/1 & 6/2	-	8.3	-	17	37.3	39.8	22.9	L
2Cg	99-109	5Y 6/2 & 6/1	few fine 5Y 3/1 mottles	8.4	-	16	48.6	36.3	15.1	L
3Cg	109-132	5Y 3/1 & 6/1	few fine 10YR 5/8 mottles	8.3	-	26	58.9	25.8	15.3	SaL
4Cg	132-160	5Y 4/1 & 5/1	many fine 10YR 5/8 mottles few fine 2.5Y 4/4 mottles	8.3	-	22	65.1	22.1	12.8	SaL
5Cg	160-183	5Y 4/1	common fine 2.5Y 5/4 & 4/4 mottles few fine 10YR 5/8 mottles	8.3	-	19	56.8	27.5	15.7	SaL
6Cg	183-218	5Y 4/1	many fine & medium 2.5Y 4/4 mottles	8.3	-	19	51.8	30.2	18.0	L

Table 36. Selected soil morphology and characterization data for Group III soils on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Canisteo clay loam-Sedge Wetland Zone-Footslope							
A1	0-23	N 2/0	-	7.4	6.2	4	29.1	40.9	30.0	CL
A2	23-43	N 2/0	-	7.4	2.8	5	29.1	40.0	30.9	CL
A3	43-61	N 2/0	few fine 5Y 5/2 mottles	7.4	2.0	2	31.9	36.8	31.3	CL
Bg1	61-74	N 3/0	few fine 5Y 5/2 mottles	7.6	2.0	23	30.9	37.1	32.0	CL
Bg2	74-86	N 3/0	few fine 5Y 5/2 mottles	7.6	1.3	12	34.0	35.3	30.7	CL
2Cg1	86-122	5Y 5/2 & 4/1	few fine 2.5Y 4/4 mottles	7.6	-	14	67.7	16.4	15.9	SaL
2Cg2	122-150	5Y 5/2 & 4/1	few fine 2.5Y 4/4 mottles Mn & 7.5YR 3/5 Fe concretions	7.9	-	12	72.6	13.4	14.0	SaL
3Cg	150-208	5Y 5/1 & 4/1	few fine 2.5Y 4/4 mottles few m/c 10YR 4/6 mottles Mn concretions	7.9	-	26	41.4	38.8	19.8	L

Table 37. Selected soil morphology and characterization data for Group IV soils on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 6: Okoboji silty clay loam-Pond Depression-Toeslope							
A1	0-15	N 2/0	common fine 2.5Y 4/2 mottles	7.5	8.1	23	10.3	55.4	34.3	SiCL
A2	15-28	N 2/0	2.5Y 4/4 pore linings common fine 2.5Y 3/2 mottles	7.5	5.2	16	14.7	50.7	34.6	SiCL
A3	28-48	2.5Y 2/1	-	7.6	1.7	3	11.1	52.6	36.3	SiCL
A4	48-66	2.5Y 2/0	common fine 5Y 5/2 mottles	7.7	1.1	5	11.5	54.1	34.4	SiCL
Bg1	66-79	5Y 5/1	few fine 10YR 4/6 & 2.5Y 4/4 mottles	7.8	0.2	10	6.6	60.7	32.7	SiCL
Bg2	79-104	5Y 5/1 & 6/2	few fine 2.5Y 4/4 & 7.5YR 3/3 mottles	8.0	-	18	9.5	58.3	32.2	SiCL
Cg	104-142	5Y 5/1 & 6/2	few fine 7.5YR 3/3 & 2.5Y 4/4 mottles	8.1	-	22	7.4	60.7	31.9	SiCL
2Ckg	142-170	5Y 5/1 & 6/1	common fine 10YR 4/6 mottles	8.2	-	25	32.1	41.9	26.0	SiL
3Cg	170-211	5Y 5/1 & 4/1	common f/m/c 2.5Y 4/4 mottles	8.2	-	21	44.9	37.0	18.1	L
			Well 7: Okoboji silty clay loam-Pond Depression-Toeslope							
A1	0-10	N 2/0	few fine 2.5Y 3/2 mottles	6.0	9.5	-	6.5	56.2	37.3	SiCL
A2	10-25	N 2/0	common fine 2.5Y 3/2 mottles 2.5Y 4/4 pore linings	6.0	8.9	-	8.6	55.3	36.1	SiCL
A3	25-41	N 2/0	2.5Y 3/2 pore linings and mottles	6.3	7.0	-	10.4	56.5	33.1	SiCL
A4	41-61	2.5Y 2/0, N 3/0	-	7.1	3.0	17	5.3	55.0	39.7	SiCL
Bg1	61-91	N 3/0	2.5Y 3/2 pore linings	7.0	-	12	3.3	57.1	39.6	SiCL
Bg2	91-119	N 3/0	few fine 2.5Y 5/2 mottles	7.3	-	20	2.4	64.6	33.0	SiCL
Ckg	119-140	5Y 6/2, 5/1, 6/1	few fine 10YR 4/6 mottles common fine 10YR ¾ mottles	8.1	-	37	4.1	68.7	27.2	SiCL
Cg	140-188	5Y 5/1	common fine 10YR ¾ mottles few fine 10YR 4/6 mottles	8.1	-	27	4.7	67.0	28.3	SiCL

Table 38. Selected soil morphology and characterization data for Group I soils on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 1: Nicollet clay loam-Upland Prairie-Summit							
A1	0-15	2.5Y 2/1	-	5.8	4.6	-	32.1	38.9	29.0	CL
A2	15-28	2.5Y 2/1	-	5.9	4.0	-	31.2	38.1	30.7	CL
Bw1	28-61	2.5Y 4/2	-	6.2	3.2	-	32.7	36.6	30.7	CL
Bw2	61-76	2.5Y 4/2	-	6.5	1.8	-	38.3	32.3	29.4	CL
Bg	76-99	2.5Y 4/4	few fine 10YR 5/8 mottles	7.1	0.4	2.0	45.4	30.4	24.2	L
Ckg	99-147	2.5Y 4/4, 4/1	few fine 10YR 5/8 mottles	8.0	-	16.2	39.3	40.4	20.3	L
2Ckg	147-155	5Y 4/1	common medium 10YR 5/8 mottles	8.2	-	20.2	22.5	55.8	21.7	SiL
3Cg	155-163	2.5Y 4/4	few fine 10YR 5/8 mottles	8.2	-	13.7	67.0	23.2	9.8	SaL
4Ckg	163-170	5Y 4/1	common medium 10YR 5/8 mottles	8.2	-	17.5	41.3	40.4	18.3	L
5Cg	170-180	2.5Y 4/4	few fine 10YR 5/8 mottles	8.3	-	14.8	61.7	26.4	11.9	SaL
6Ckg	180-201	5Y 4/1; 2.4Y 4/4	few fine 10YR 5/8 mottles	8.3	-	17.6	48.6	38.0	13.4	L
			Well 2: Nicollet clay loam-Upland Prairie-Shoulder							
A1	0-20	5Y 2/1	-	5.6	4.9	-	28.3	42.5	29.2	CL
A2	20-41	5Y 2/1	few fine 2.5Y 4/2 mottles	5.7	3.5	-	19.1	47.7	33.2	CL
Bw	41-61	2.5Y 4/2	-	6.5	1.8	-	20.8	47.0	32.2	CL
Bg1	61-79	2.5Y 4/2	few fine 2.5Y 4/4 mottles	6.7	1.0	-	18.1	50.2	31.8	SiCL
Bg2	79-97	5Y 4/1; 5Y 6/2	few fine 2.5Y 4/4 mottles few fine 10YR 5/8 mottles	7.0	0.4	-	16.7	54.0	29.4	SiCL
BCg	97-107	5Y 4/1; 5Y 6/2	few fine 2.5Y 4/4 mottles common fine 10YR 5/8 mottles	7.5	-	4.0	19.5	56.4	24.1	SiL
2Ckg	107-122	5Y 4/1; 5Y 6/2	many medium 10YR 5/8 mottles	8.0	-	18.9	8.3	71.3	20.4	SiL
3Ckg	122-137	5Y 4/1; 5Y 6/2	few fine to medium 10YR 5/8 mott. few fine 7.5YR 4/6 mottles	8.2	-	17.8	24.2	58.5	17.2	SiL
3Cg1	137-173	5Y 4/1; 5Y 6/2	many medium 10YR 5/8 mottles	8.5	-	20.1	24.1	60.1	15.8	SiL
3Cg2	173-201	2.5Y 5/2	many medium 10YR 5/8 mottles	8.5	-	20.6	18.2	66.2	15.6	SiL

Table 39. Selected soil morphology and characterization data for Group II soils on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Webster clay loam-Upland Prairie-Backslope							
A1	0-20	2.5Y 2/0	-	6.3	5.8	-	27.5	43.5	29.0	CL
A2	20-38	2.5Y 2/0	-	6.6	4.6	-	23.7	44.3	32.0	CL
A3	38-53	2.5Y 2/0	-	6.9	2.2	-	22.7	42.0	35.3	CL
Bg	53-74	5Y 4/1	-	7.3	0.7	-	23.6	43.2	33.2	CL
Bkg	74-86	5Y 6/2	very few fine 10YR 5/8 mottles	7.8	0.3	11.3	35.2	37.5	27.3	CL
Ckg1	86-102	5Y 6/2	few fine 10YR 5/8 mottles	8.1	0.2	17.0	42.1	36.7	21.2	L
Ckg2	102-124	5Y 6/2; 5Y 5/1	common fine 10YR 5/4&5/8 mott.	8.4	-	18.1	40.3	39.4	20.3	L
Cg1	124-152	5Y 6/2; 5Y 5/1	many fine 10YR 5/4&5/8 mottles few 7.5YR ¾ pore linings	8.4	-	18.3	44.1	36.8	19.1	L
Cg2	152-165	5Y 5/1	many fine to coarse 10YR 5/4, 5/8, 7.5YR ¾ mottles	8.2	-	17.7	35.8	43.6	20.6	L
2Cg	165-200	10YR 5/8; 7.5YR 3/4	-	8.3	-	18.5	75.4	15.2	9.4	SaL
			Well 4: Delft clay loam-Upland Prairie-Backslope							
A1	0-20	2.5Y 2/0	-	7.3	6.6	2.7	21.4	47.2	31.4	CL
A2	20-36	2.5Y 2/0	few fine 2.5Y 3/2 mottles	7.5	6.8	3.3	14.8	52.2	33.0	SiCL
A3	36-61	2.5Y 3/0	few fine 2.5Y 3/2 mottles	7.6	4.2	2.0	14.7	51.1	34.2	SiCL
AB	61-79	5Y 3/1	few fine 2.5Y 3/2 mottles	7.6	2.4	2.4	13.0	51.2	35.8	SiCL
Bg1	79-86	5Y 4/1&5/1	few fine 2.5Y 3/2 mottles	8.0	1.2	3.6	15.8	50.6	33.6	SiCL
Bg2	86-107	5Y 5/2	few fine 10YR 5/8 mo, ff 4/1depl.	7.9	1.2	6.9	19.2	51.4	29.4	SiCL
2Ckg	107-130	5Y 6/2 & 5/1	few fine 10YR 5/8	8.2	-	14.5	51.9	31.8	16.3	L
3Cg	130-140	5Y 6/2 & 5/1	common fine 10YR 5/4 & 5/8 mott.	8.3	-	13.3	82.6	11.7	5.7	LS
4Cg1	140-155	5Y 5/1	few fine 7.5YR 3/4 mottles	8.2	-	18.6	55.0	31.3	13.7	SaL
4Cg2	155-175	5Y 5/1 & 2.5Y 4/4	few fine 10YR 5/4 & 5/8	8.2	-	17.0	51.9	30.0	18.1	L
4Cg3	175-206	5Y 5/2 and 5Y 5.1	few fine 10YR 5/4 and 5/8 mottles	8.3	-	16.2	57.2	27.9	14.9	SaL

Table 40. Selected soil morphology and characterization data for Group III soils on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 5: Delft clay loam-Wet Prairie-Footslope							
A1	0-25	N 2/0	-	7.7	8.8	3.8	18.5	49.1	32.4	CL
A2	25-51	N 2/0	-	7.8	3.5	2.4	13.9	54.6	31.5	SiCL
A3	51-74	N 3/0	-	7.8	2.1	2.5	12.3	54.9	32.8	SiCL
ABg	74-89	N 3/0	few fine 2.5Y 4/4 mottles	8.1	1.3	4.0	14.4	54.6	31.0	SiCL
Bg	89-107	5Y 4/1	many medium 2.5Y 4/4 mottles few fine 10YR 5/8 mottles	8.1	0.2	10.1	12.3	62.5	25.2	SiL
Cg	107-117	5Y 5/1	common fine 10YR 5/8 mottles	8.3	-	12.6	31.2	51.7	17.1	SiL
2Cg	117-127	5Y 5/1, 6/2, 3/1	-	8.3	-	12.6	50.8	34.6	14.6	L
3Cg	127-150	5Y 5/1 & 6/2	few medium 10YR 5/8 mottles	8.5	-	16.1	73.4	16.4	10.2	SaL
4Cg1	150-175	5Y 5/1	few medium 10YR 5/4 and 5/8 mot. many fine 2.5Y 4/4 mottles	8.3	-	17.4	54.7	32.4	12.9	SaL
4Cg2	175-213	5Y 5/1 & 5/2	few fine 10YR 5/8 mottles	8.2	-	18.5	54.8	32.3	12.9	SaL
			Well 6: Delft silty clay loam-Sedge Wetland Zone-Footslope							
A1	0-23	N 2/0	-	7.5	12.1	2.0	14.8	54.1	31.1	SiCL
A2	23-38	N 2/0	few 10YR ¾ and 4/6 pore linings few fine 4/1, 4/2 mottles	7.7	9.7	2.4	12.6	56.5	30.9	SiCL
A3	38-51	N 3/0	few 10YR & 7.5YR 4/6 pore linings few fine 4/1 & 4/2 mottles	7.8	2.7	1.8	11.1	59.0	29.9	SiCL
A4	51-64	N 3/0	common 7.5YR 4/6 pore linings	8.0	1.3	2.4	6.8	71.6	21.6	SiL
Bg1	64-76	5Y 4/1	few fine 2.5Y 4/2 & 4/4 mottles common 7.5YR 4/6 pore linings	8.2	0.5	5.1	5.2	62.8	32.0	SiCL
Bg2	76-94	5Y 4/1	few 7.5YR 4/6 pore linings many medium 2.5Y 4/4 mottles	8.1	0.1	9.6	6.0	65.4	28.6	SiCL
BCg	94-107	5Y 4/1	common fine-medium 2.5Y 4/4 mot	8.1	-	12.6	17.4	58.3	24.3	SiL
2Cg	107-122	5Y 4/1	-	8.3	-	12.1	45.4	38.9	15.7	L
3Cg1	122-147	2.5Y 4/4, 4/2	-	8.5	-	12.8	67.7	22.9	9.4	SaL
3Cg2	147-183	5Y 4/1	few medium 2.5Y 4/4 mottles few coarse 10YR 5/8 mottles	8.6	-	14.3	70.8	19.7	9.5	SaL

Table 41. Selected soil morphology and characterization data for Group IV soils on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
Well 7: Okoboji silty clay loam-Pond Depression-Toeslope										
A1	0-20	N 2/0	-	6.6	19.9	-	5.2	60.7	34.1	SiCL
A2	20-41	N 2/0	-	6.9	12.1	-	7.3	62.1	30.6	SiCL
A3	41-64	N 2/0	few fine 2.5Y 4/4 mottles few fine 5Y 4/1 Fe depletions	7.3	3.1	5.5	3.1	60.4	36.5	SiCL
A4	64-86	N 2/0	few medium 2.5Y 4/4 mottles few 10YR 4/3 pore linings few fine/medium 5Y 4/1 depletions	7.5	1.8	3.1	1.8	58.9	39.3	SiCL
Bg	86-97	5Y 4/1	few fine & medium 2.5Y 4/4 mott few 10YR 4/3 pore linings	7.5	1.2	4.1	1.2	62.8	36.0	SiCL
Ckg1	97-127	5Y 6/2	few fine-coarse 2.5Y 4/4 mottles	7.8	0.4	26.2	1.9	76.0	22.1	SiL
Ckg2	127-140	5Y 4/1	common fine-coarse 2.5Y 4/4 mot	7.9	-	17.0	8.3	69.9	21.8	SiL
Ckg3	140-183	5Y 4/1 and 5Y 6/2	few fine 2.5Y 4/4 mottles	7.9	-	21.4	3.6	70.0	26.4	SiL
Well 8: Wacousta silt loam-Pond Depression-Toeslope										
A1	0-13	N 2/0	-	7.4	14.5	4.2	4.1	72.2	23.7	SiL
A2	13-23	N 2/0	many fine 2.5Y 4/2 mottles	7.5	6.7	3.1	3.0	64.5	32.5	SiCL
Bg1	23-28	2.5Y 4/2	-	7.8	0.9	8.5	1.7	65.1	33.2	SiCL
Bg2	28-41	5Y 4/1 & 5/1	few medium 10YR 4/3 mottles few fine 7.5YR 3/6 mottles few 7.5YR 3/6 pore linings	8.0	0.8	24.5	2.0	69.0	29.0	SiCL
Ckg1	41-53	5Y 4/1; 5/1; 4/2	few medium-coarse 7.5YR 3/6 mot. common 7.5YR 3/6 pore linings	8.0	-	22.8	5.0	71.2	23.8	SiL
Ckg2	53-84	5Y 5/1; 2.5Y 4/2	common 7.5YR 3/6 pore linings	8.0	-	22.1	4.4	73.8	21.8	SiL
Cg1	84-114	5Y 5/1 & 4/1	common 7.5YR 3/6 pore linings few fine 10YR 4/4 mottles	8.0	-	22.8	3.3	72.6	24.1	SiL
Cg2	114-142	5Y 5/1 & 4/1	common medium 10YR 4/4 mottles	8.0	-	22.5	2.4	74.0	23.6	SiL
2Ckg	142-168	5Y 5/1; 2.5Y 4/2	few medium 10YR 4/6 mottles	8.0	-	18.8	12.7	60.8	26.5	SiL
3Ckg	168-183	5Y 5/1; 2.5Y 4/2	few medium 10YR 4/6 mottles	7.9	-	17.8	4.0	66.9	29.1	SiCL

Table 42. Selected soil morphology and characterization data for Group I and II soils on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Group I: Nicollet clay loam-Upland Prairie-Shoulder							
A1	0-18	5Y 2/1	-	5.8	3.9	-	37.9	32.3	29.8	CL
A2	18-33	5Y 2/2	-	5.8	3.4	-	32.3	36.6	31.1	CL
AB	33-43	5Y 2/2; 2.5Y 4/2	-	6.0	2.5	-	32.1	37.7	30.2	CL
Bw	43-64	2.5Y 4/2	-	6.6	2.1	-	34.9	35.9	29.2	CL
Bg	64-79	2.5Y 4/2; 10YR 4/3	few fine 10YR 5/8 mottles	6.9	1.3	-	37.2	36.6	26.2	L
2Ckg	79-84	2.5Y 4/4	few fine 10YR 5/8 mottles few medium 10YR 4/3, 4/2 mottles	7.7	0.4	13.2	47.2	34.5	18.3	L
3Ckg1	84-99	2.5Y 4/2; 10YR 4/3	few fine 2.5Y 4/4 mottles	8.0	0.5	16.8	33.0	48.7	18.3	L
3Ckg2	99-112	5Y 5/1	few coarse 10YR 5/8 mottles	8.0	-	20.3	34.8	46.4	18.8	L
4Cg	112-124	2.5Y 4/4	few fine 10YR 5/8 mottles few medium 5Y 4/1 Fe depletions	8.1	-	19.4	48.7	36.2	15.1	L
5Ckg	124-158	5Y 5/1	few medium 2.5Y 5/4 mottles few fine 7.5YR 4/6 mottles	8.2	-	21.1	17.0	66.0	17.0	SiL
6Cg	158-170	10YR 5/4	few fine 5Y 5/1 Fe depletions	8.3	-	20.8	44.6	44.3	11.1	L
7Ckg	170-203	10YR 5/4	common medium 10YR 5/8 mottles few medium 5Y 5/1 Fe depletions	8.3	-	23.1	7.0	78.2	14.8	SiL
			Group II: Webster clay loam-Upland Prairie-Backslope							
A1	0-23	2.5Y 2/0	few fine 10YR 5/8 mottles	6.5	4.5	-	38.0	34.5	27.5	CL
A2	23-46	2.5Y 2/0	few fine 10YR 5/8 mottles common fine 2.5Y 4/2 mottles	7.5	1.7	-	36.3	32.9	30.8	CL
Bg	46-61	5Y 4/1	few fine 10YR 5/8 mottles few fine 2.5Y 4/2 mottles	7.9	1.5	10.2	39.6	32.5	27.9	CL
Bkg	61-81	5Y 4/1	few medium 10YR 5/8 mottles	8.1	0.3	16.4	40.5	35.4	24.1	L
Ckg1	81-122	5Y 5/1	common medium 10YR 5/8 mottles	8.4	-	20.4	42.3	35.9	21.8	L
Ckg2	122-168	5Y 5/1 & 6/2	few medium-coarse 10YR 4/6 mot. few 10YR 4/6 pore linings	8.5	-	19.9	40.7	36.8	22.5	L
Cg	168-208	5Y 4/1	many fine 2.5Y 5/4 mottles	8.4	-	18.7	43.5	36.7	19.8	L

Table 43. Selected soil morphology and characterization data for Group III soils on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 3: Canisteo loam-Wet Prairie I-Footslope							
A1	0-25	N 2/0	-	7.3	4.6	3.8	38.7	35.3	26.0	L
A2	25-46	N 2/0	few fine 2.5Y 4/2 mottles	7.7	2.9	5.6	43.0	31.7	25.3	L
Bkg2	46-66	2.5Y 4/2	-	7.7	1.2	9.1	43.0	32.1	24.9	L
Bkg2	66-76	5Y 4/1; 2.5Y 4/2	few fine-medium 10YR 4/6 mott.	7.9	0.2	15.9	44.6	32.9	22.5	L
Cg1	76-99	5Y 5/1	common medium 10YR 4/6 mott.	8.1	-	16.9	45.5	34.2	20.3	L
Cg2	99-109	4/6; 2.5Y 4/4	few fine/medium 5Y 5/1 Fe depl.	8.1	-	20.5	43.9	35.0	21.1	L
Cg3	109-140	5Y 5/1	few fine 10YR 4/6 mottles common medium 2.5Y 4/4 mott.	8.1	-	19.5	43.7	35.3	21.0	L
Cg4	140-145	5Y 5/1	many medium 2.5Y 4/4 mottles few 7.5YR 4/6 pore linings	8.2	-	19.5	40.6	37.6	21.8	L
Cg5	145-150	5Y 5/1	few medium 7.5Y 4/6 mottles few medium 2.5Y 4/4 mottles	8.3	-	17.8	41.8	36.9	21.3	L
2Cg	150-165	5Y 5/1	many fine-medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	8.2	-	21.1	30.3	47.8	21.9	L
3Cg1	165-216	2.5Y 4/4	common medium 7.5YR 4/6 mott. few 7.5YR 4/6 pore linings few medium 5Y 5/1 Fe depletions	8.1	-	20.6	39.7	40.4	19.9	L
			Well 4: Canisteo loam-Wet Prairie II-Footslope							
A1	0-20	N 2/0	-	7.9	4.1	11.5	40.3	34.5	25.2	L
A2	20-48	2.5Y 2/1	few fine 2.5Y 4/2 mottles	8.1	2.4	13.2	42.0	34.9	23.1	L
Bg	48-79	5Y 4/1; 5/1; 6/2	few fine-medium 10YR 5/8 mottles	8.2	0.7	16.0	43.1	35.4	21.5	L
Ckg1	79-102	5Y 5/1 & 6/2	few medium-coarse 10YR 5/8 mot.	8.3	-	24.8	49.6	35.1	15.3	L
Ckg2	102-122	5Y 5/1 & 6/2	few medium-coarse 10YR 5/8 mot.	8.3	-	19.6	50.9	36.3	12.8	L
Cg1	122-142	5Y 5/1 & 6/2	common medium 10YR 5/8 mott. common medium 2.5Y 4/4 mottles	8.2	-	27.5	50.9	34.0	15.1	L
Cg2	142-165	2.5Y 4/4	few fine-medium 10YR 4/6 mottles	8.3	-	22.0	54.5	32.0	13.5	L
2Cg1	165-180	5Y 5/1 & 6/2	common medium 2.5Y 4/4 mottles few fine 10YR & 7/5YR 4/6 mott.	8.3	-	22.4	45.7	38.7	15.6	L
2Cg2	180-218	5Y 5/1 & 6/2	common medium 7.4YR 4/6 mott.	8.2	-	17.5	43.4	37.9	18.7	L
			Well 5: Canisteo clay loam-Cattail Zone-Footslope							
Ak	0-20	N 2/0	few 2.5Y 4/2 mottles	7.5	2.7	19.2	28.6	42.8	28.6	CL
A	20-61	N 2/0	few 10YR 4/6 pore linings	7.8	2.1	4.0	25.4	44.1	30.5	CL
Bg1	61-79	2.5Y 3/1	few fine 10YR 4/6 mottles	7.9	0.7	5.1	29.3	39.3	31.4	CL
Bg2	79-102	5Y 5/1 & 6/2	few fine 10YR 4/6 mottles	8.0	-	10.9	20.0	51.2	28.8	SiCL
2Ckg	102-122	5Y 5/1	few medium 2.5Y 4/4 mottles few fine 10YR 4/6 mottles	8.1	-	15.9	38.4	37.9	23.7	L
2Cg	122-155	5Y 5/1 & 6/2	common fine 10YR 4/6 mottles few fine 2.5Y 4/4 mottles	8.1	-	16.0	37.4	39.4	23.2	L
3Cg	155-203	5Y 5/1 & 6/2	common medium 2.5Y 4/4 mottles few fine 7.5YR 4/6 mottles	8.1	-	18.7	42.5	36.6	20.9	L

Table 44. Selected soil morphology and characterization data for Group IV soils on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
A1	0-15	N 2/0	-	6.8	8.2	-	10.6	55.1	34.3	SiCL
A2	15-36	2.5Y 2/0	few fine 5Y 5/2 mottles	7.2	2.9	-	8.6	57.4	34.0	SiCL
A3	36-56	2.5Y 2/0	common fine 5Y 4/3, 4/2 mottles	7.5	1.8	4.5	6.0	56.0	38.0	SiCL
AB	56-66	2.5Y 2/0 & 3/1	common fine 5Y 4/3 mottles few fine 10YR 4/6 mottles	7.8	1.3	12.4	5.4	59.6	35.0	SiCL
Bg	66-84	5Y 4/1	many fine 10YR 4/6 mottles few fine 5Y 4/3 mottles	7.9	0.6	12.3	6.4	60.1	33.5	SiCL
Cg	84-91	5Y 4/1 & 5/1	common fine 10YR 4/6 mottles few medium 2.5Y4/2 & 4/4 mot	8.1	-	11.6	14.9	64.1	21.0	SiL
2Cg1	91-109	5Y 5/1	few fine 10YR 4/6 mottles few medium 2.5Y 4/4 mottles	8.4	-	26.1	45.2	43.7	11.1	L
2Cg2	109-157	5Y 5/1 & 6/2	common fine 10YR 4/6 mottles few fine 2.5Y 4/4 mottles	8.5	-	18.0	48.7	34.3	17.0	L
3Cg1	157-170	5Y 4/1	few fine 10YR 4/6 mottles common medium 2.5Y 4/4 mottles	8.3	-	20.6	60.2	31.5	8.3	SaL
3Cg2	170-198	5Y 5/1	few fine 2.5Y 4/4 mottles	8.6	-	19.9	54.8	34.6	10.6	SaL
4Cg	198-211	2.5Y 4/2, 4/4	few fine 10YR & 7.5YR 4/6 mottles	8.6	-	12.5	81.0	13.7	5.3	LS

Table 45. Selected soil morphology and characterization data for summit to backslope soils on transect 3 in Gordon's Marsh

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 1: Nicollet clay loam-Alfalfa food plot-Summit							
Ap	0-25	10YR 2/1	-	5.3	4.3	-	23.4	46.7	29.9	CL
A	25-41	10YR 2/1	-	6.0	2.7	-	28.2	41.8	30.0	CL
Bw1	41-53	10YR 4/2	-	6.4	1.4	-	33.6	35.6	30.8	CL
Bw2	53-69	10YR 4/2 & 3/2	-	6.7	0.9	-	34.9	37.8	27.3	CL
Bg	69-84	2.5Y 4/2	few fine 2.5Y 5/4 & 10YR 4/6 mott.	7.1	-	4.8	35.2	40.6	24.2	L
Cg	84-102	2.5Y 4/2 & 5/2	few fine 2.5Y 5/4 mottles common fine 10YR 4/6 mottles	7.7	-	4.5	35.0	44.8	20.2	L
2Ckg	102-127	2.5Y 5/2	few fine 7.5YR 3/2 & 10YR 4/6 mo many fine-medium 2.5Y 5/6 mottles	8.2	-	23.7	21.3	63.8	14.9	SiL
2Cg	127-152	5Y 5/2	common medium 10YR 4/6 mottles common medium 2.5Y 5/6 mottles	8.2	-	20.0	30.6	54.3	15.1	SiL
3Cg	152-165	2.5Y 5/2 & 4/4	many medium 10YR 4/6 mottles	8.4	-	22.9	59.6	29.3	11.1	SaL
4Ckg	165-193	2.5Y 5/2	many medium 2.5Y 5/6 mottles common fine 10YR 4/6 mottles	8.2	-	18.8	37.8	48.9	13.3	L
5Ckg	193-211	2.5Y 6/2 & 5/2	few medium 7.5YR 4/6 mottles	8.2	-	22.2	25.4	56.9	17.7	SiL
			Well 2: Delft clay loam-Mowed Trail-Summit							
A1	0-13	7.5YR 2/0	-	5.8	7.7	-	21.5	49.6	28.9	CL
A2	13-38	7.5YR 2/0	-	5.9	6.3	-	15.8	52.6	31.6	SiCL
A3	38-58	2.5Y 2/0	-	5.8	5.2	-	11.9	54.6	33.5	SiCL
A4	58-74	2/5Y 3/1	-	6.0	3.9	-	11.5	54.4	34.1	SiCL
A5	74-86	10YR 3/1	few fine 2.5Y 4/2 mottles	5.8	4.1	-	13.3	52.5	34.2	SiCL
AB	86-102	2.5Y 4/2 & 3/1	few fine 10YR 4/4 mottles	6.0	2.2	-	13.2	49.3	37.5	CL
2Bg1	102-117	2/5 Y 4/2 & 3/1	few fine 10YR 4/4 & 4/6 mottles	6.1	0.8	-	29.8	35.3	34.9	CL
2Bg2	117-137	5Y 4/1 & 5/2	few fine 2.5Y 4/4 mottles	6.3	-	-	35.5	32.9	31.6	CL
2Bg3	137-155	5Y 5/1 & 5/2	many fine 2.5Y 4/4 mottles	6.7	-	-	37.2	32.7	30.1	CL
2Cg	155-178	5Y 5/1 & 6/2	common fine 2.5Y 4/4 & 5/4 mott.	7.5	-	17.1	37.7	35.7	26.6	L
2Ckg	178-201	5Y 5/1 & 6/2	common fine 2.5Y 5/4 mottles few fine-medium 7.5YR 4/6 mottles	7.9	-	15.9	37.5	39.8	22.7	L
			Well 3: Delft loam-Forested Backslopes							
A1	0-20	7.5YR 2/0	-	6.1	4.6	-	38.8	36.2	25.0	L
A2	20-36	2.5Y 2/1	-	6.4	3.8	-	35.2	37.8	27.0	CL
A3	36-51	2.5Y 2/1	few fine 10YR 3/2 mottles	6.7	3.0	-	38.0	35.9	26.1	L
AB	51-64	2.5Y 3/1	few fine 10YR 3/2 mottles	6.9	2.1	-	39.5	35.8	24.7	L
Bg1	64-79	10YR 3/1	common fine-medium 2.5Y 3/2 mot	7.2	1.1	-	41.6	34.8	23.6	L
Bg2	79-91	2/5Y 4/2; 4/4; 3/1	few fine 10YR 4/6 & 2.5Y 4/4 mott.	7.5	0.5	-	38.1	37.7	24.2	L
Bg3	91-99	2.5Y 4/2 & 4/4	few fine 10YR 4/8 mottles	7.8	-	13.8	39.7	40.2	20.1	L
2Ckg	99-107	2.5Y 5/4 & 6/2	few fine 10YR 4/4 mottles	8.1	-	17.5	26.8	55.3	17.9	SiL
3Ckg1	107-119	2.5Y 6/2	many fine 2.5Y 4/4 mottles few medium 2.5Y 5/6 mottles	8.4	-	27.7	9.8	73.9	16.3	SiL
3Ckg2	119-135	2.5Y 6/2	common fine-medium 2.5Y 5/6 mot few medium 10YR 4/6 mottles	8.5	-	24.3	5.5	84.8	9.7	SiL
3Ckg3	135-168	2.5Y 6/2	few fine-medium 10YR 4/6 mottles few fine 2.5Y 5/6 mottles	8.4	-	23.3	6.2	80.9	12.9	SiL
4Cg	168-183	2/5Y 5/2 & 4/4	few medium 2.5Y 56 mottles	8.6	-	18.0	58.2	30.9	10.9	SaL
5Cg1	183-193	2.5Y 5/2 & 6/2	few fine 2.5Y 5/6 mottles	8.6	-	17.5	47.1	42.2	10.7	L
5Cg2	193-203	2.5Y 5/2 & 6/2 & 4/4	few fine 10YR 4/6 mottles	8.6	-	19.0	50.9	39.1	10.0	L

Table 46. Selected soil morphology and characterization data for footslope and toeslope soils on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Matrix Color	Redoximorphic Features	pH	O.M %	CCE %	Sand %	Silt %	Clay %	Texture
			Well 4: Canisteo loam-Footslope							
A1	0-15	N 2/0	-	7.1	6.6	3.4	33.0	42.7	24.3	L
A2	15-33	N 2/0	few fine 2.5Y 4/2 mottles	7.4	4.2	4.9	33.7	42.1	24.2	L
2A	33-53	N 2/0	few fine 2.5Y 4/2 mottles	7.7	1.0	6.3	52.5	31.5	16.0	L
2Bg1	53-69	2.5Y 3/1	few fine 2.5Y 4/4, 4/2 mottles	7.9	0.2	13.0	54.0	30.6	15.4	SaL
2Bg2	69-89	2.5Y 3/1 & 5/1	few fine 2.5Y 4/4 mottles	7.9	0.3	14.6	48.2	34.5	17.3	L
2Cg1	89-107	5Y 5/1	common fine 2.5Y 4/4 mottles	8.0	-	21.0	45.5	33.6	20.9	L
			few fine 2.5Y 5/6 mottles							
2Cg2	107-122	5Y 5/1	common f/m 2.5Y 4/4 mot	8.0	-	22.0	39.4	37.3	23.3	L
			few fine 10YR 4/6 mottles							
3Cg	122-157	5Y 5/1	common f/m 2.5Y 4/4 mot	7.9	-	21.0	28.9	46.9	24.2	L
4Cg	157-193	5Y 5/1	few medium 2.5Y 4/4 mottles	7.9	-	18.7	40.2	37.6	22.2	L
			few m/c 10YR ¾ mottles							
			Well 5: Klossner muck-Reed Canarygrass Pond-Footslope							
Oi	0-10		-	6.5	.-	ND	-	-	-	-
A1	10-38	2.5Y 2/0	-	6.9	-	18.0	12.9	55.8	31.3	SiCL
A2	38-71	2.5Y 2/0	-	7.0	3.1	7.3	21.6	50.8	27.6	SiCL
2A1	71-99	2.5Y 2/0	few fine 2.5Y 4/2 mottles	7.4	2.9	5.2	38.2	38.0	23.8	L
2A2	99-119	2.5Y 2/0	common f/m 2.5Y 4/2 mot	7.9	7.0	1.5	43.8	37.1	19.1	L
3Cg	119-157	2.5Y 2/0 5Y 5/1, 4/1	few medium 2.5Y 4/4 mottles	8.0	9.2	1.3	11.7	62.2	26.1	SiL
4Cg1	157-180	5Y 5/1 & 4/4	common fine 2.5Y 4/4 mottles	8.2	18.8	-	39.8	45.9	14.3	L
4Cg2	180-221	5Y 4/1 & 2.5Y 4/2	common fine 7.5YR ¾ mottles	8.1	20.3	-	35.6	44.1	20.3	L
			few fine 10YR 4/6 mottles							
			Well 6: Klossner muck-Reed Canarygrass Pond-Toeslope							
Oi	0-8	-	-	6.6	45.8	-	-	-	-	Fibrous
Oa	8-25	N 2/0	-	6.5	34.6	-	9.4	71.9	18.7	SiL
A	25-46	5Y 2/1	-	6.5	12.8	-	5.6	57.6	36.8	SiCL
Cg	46-51	5Y 7/2 & 4/1	few 10YR ¾ pore linings	6.8	4.8	-	6.4	61.6	32.0	SiCL
2A1	51-81	2.5Y 2/1	few 10YR ¾ pore linings	6.8	14.8	-	2.8	61.3	35.9	SiCL
2A2	81-102	2.5Y 2/0	few 10YR ¾ pore linings	7.0	7.3	2.7	1.8	60.0	38.2	SiCL
2A3	102-142	2.5Y 2/0	few fine 10YR ¾ pore linings	7.5	4.9	7.6	2.6	60.1	37.3	SiCL
			few medium 2.5Y 4/2 mottles							
2A4	142-191	2.5Y 2/0 & 5Y 2/1	few fine 10YR ¾ pore linings	7.5	5.3	4.2	1.7	60.2	38.1	SiCL
			few medium 2.5Y 4/2 mottles							
2Cg	191-198	2.5Y 6/2 & 5Y 4/1	-	7.5	8.0	4.0	6.6	74.6	18.8	SiL
			Well 7: Klossner muck-Reed Canarygrass Pond-Toeslope							
Oi	0-5	-	-	6.5	54.2	-	-	-	-	-
A1	5-28	N 2/0	-	6.6	12.9	-	4.9	62.4	32.7	SiCL
A2	28-43	N 2/0 & 5Y 2/1	-	6.7	9.6	-	4.5	57.7	37.8	SiCL
A3	43-61	N 2/0	-	6.9	10.2	-	2.9	60.5	36.6	SiCL
A4	61-79	2.5Y 2/0	-	7.1	7.8	4.0	2.7	58.2	39.1	SiCL
A5	79-102	2.5Y 2/0	-	7.3	5.9	2.2	2.4	57.9	39.7	SICL
A6	102-109	2.5Y 5/4 & 2.5Y 2/0	-	7.4	5.2	3.3	4.9	61.3	33.8	SiCL
A7	109-142	2.5Y 2/0	few fine 10YR ¾ mottles	7.6	5.0	4.5	1.8	57.0	41.2	SiL
			very few fine 2.5Y 3/2 mottles							
A8	142-188	2.5Y 2/0 % 5Y 2/1	few fine 10YR ¾ mott.	7.7	2.7	14.0	2.9	61.1	36.0	SiCL
			few 10YR ¾ pore linings							
			few medium 2.5Y 3/2 mottles							

Summary

Soil hydromorphology of restored prairie-wetland hillslopes were studied on the Des Moines Lobe. Four groups were developed to describe the variability in soils, vegetation, and slope position on the hillslopes. Group I soils included upland prairie soils on summit and shoulder slopes with moderately well and somewhat poor drainage. Dominant soils included Clarion and Nicollet soils with some taxadjuncts. The soil classification is fine-loamy, mixed, superactive, mesic Typic or Aquic Hapludoll. Group II soils included upland prairie soils on backslopes with poor drainage. The dominant soils were Webster, Delft, and Canisteo soils with some taxadjuncts present. Soil classification was fine loamy/silty, mixed, superactive, (calcareous), mesic Typic or Cumulic Endoaquoll. Group III soils included wet prairies or sedge wetlands on footslopes with poor drainage. The dominant soils were Canisteo and Delft soils with some intergrades present. Soil classification was fine loamy/silty, mixed, superactive, calcareous, mesic Cumulic or Typic Endoaquoll. Group IV soils occurred on pond depressions on toeslopes with poor and very poor drainage. The dominant mineral soils were Okoboji and Glencoe soils. Dominant organic soils were the Klossner soils. Soil classification for mineral soils was fine/fine silty/fine loamy, mixed/smectitic, mesic Cumulic Vertic Endoaquoll. Soil classification for organic soils was fine-loamy, mixed, euic, mesic Terric Haplosaprist. Groups II to IV in prairie-wetland hillslopes are hydric based on positive correlation between soil morphology and hydrology.

Group I soils on a ditch-drained hillslope had relict redoximorphic features in the lower sola. Shallowest water table depths occurred during the months of March to May, the onset of the growing season, and deepest water table depths occurred during the months of August to October, near the end of the growing season. Group IV soils were ponded between 3 to 12 months per year. Group III soils were ponded 0-3 months per year. Group I soils have slightly acid loamy Bw horizons underlying moderately acid black loam mollic epipedons. The Bw horizon had variable moist chromas of 2-4. In Nicollet soils, the Bw horizons underlies moderately acid to alkaline clay loam Bg horizons.

Group III soils are slightly alkaline and calcareous throughout the sola. These areas dry out sometime during the growing season where water moves upward in the solum by unsaturated flow in response to plant uptake and evapotranspiration. Evaporation of water leaves dissolved materials in the sola. Group III soils had slightly alkaline clay loam mollic epipedons overlying slightly alkaline clay loam Bg horizons. Soil matrices had low chromas, reflective of Fe reduction and the dark mollic epipedon. The upper part of the Bg horizons had, in general, low chroma mottles or redox depletions whereas the lower Bg horizons display mixture of low and high chroma mottles. The vegetation in Group III soils influence the local hydrology by causing a depression in mean water table depth, reflecting the presence of relatively more phreatophytes or hydrophytes that can act like a water pump. Group IV soils had thick black silty clay loam to clay neutral mollic epipedons overlying thin Fe-reduced Bg horizons. These soils had shallowest depth to redoximorphic features, which occurred as low chroma mottles or high/low chroma pore linings in the upper soil horizons. Soil morphology correlated with hydrology. Class IV soils are on discharge areas as indicated by an upward trend in mean water table depths along the soil surface.

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CHAPTER 3: SOIL LANDSCAPE RELATIONSHIPS ON RESTORED PRAIRIE-WETLAND HILLSLOPES IN CENTRAL IOWA: SOURCES OF VARIABILITY AND CARBON CONTENTS

A paper to be submitted to the Soil Science Society of America Journal

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Abstract

Restoration of cultivated hillslopes into prairie and wetland ecosystems influences soil quality. Understanding and elucidating the sources of soil variability are important in assessing the ecological and environmental functions of these ecosystems. A nested sampling design was established within three wetland complexes on the Des Moines Lobe to study landscape relationships on restored prairie-wetland hillslopes. Soils were sampled at three depths (0-15, 15-30, 30-45cm) on four transect groups on three hillslopes per wetland complex. Groups were assigned for each hillslope element: group I: upland prairie on summits with moderately well drained soils; group II: upland prairies on backslopes with poorly drained soils; group III: wet prairies to sedge wetland zones on footslopes with poorly drained calcareous soils; group IV: closed pond wetlands on toeslopes with very poorly drained soils. Soils were analyzed to determine the variability in extractable bases, pH, particle size distribution, organic carbon (C), total C, bulk density, and available P. Soil depth explained most of the systematic variability in available K, available P, total C, and organic C in upland prairies and wetland ecosystems. Slope position explained most of the variability in sand and fine silt in both ecosystems. Sources of variability differed among upland prairie and wetland ecosystems for coarse silt, clay, bulk density, extractable Ca and Mg, CEC, pH, extractable Mn, and extractable Fe. Transect and soil depth explained most of the variability within each group. Group III and IV soils had the highest total and organic C amounts and variability within each wetland complex. Total and organic C amounts can be used as reference points for long term monitoring of C

dynamics on these restored hillslopes. Spatial relationships and variability attributable to site, transect, vegetation, slope position, and depth should be considered when assessing restored hillslopes.

Introduction

Mollisols are the major soil order on landscapes in central Iowa. Mollisols are characterized by the presence of the mollic epipedon. Differences in soils within an area are generally attributed to differences in parent material, topographic position, and drainage (Khan and Fenton, 1994). In general, soils on summits to backslopes formed in glacial till whereas footslope and toeslope soils formed in fine loamy sediment. Melanization is the dominant process in Mollisols and is defined as the darkening of the soil by addition and decomposition of organic matter in the mineral soil (Buol et al., 1995). This process involves numerous specific subprocesses such as root extension into the soil profile, microbial decomposition of organic materials, humification, illuviation/eluviation of organic and inorganic constituents along voids between peds, and the formation of stable resistant humic substances. Cumulization is a significant process in Iowa landscapes. It involves the overthickening of mollic epipedons downslope as a result of erosion, transportation, and deposition of sediment from upslope. Fenton (1983) reported four sequences in textural differentiation in Mollisols: leaching of carbonates, clay formation, chemical alteration of clay minerals, and clay translocation. The continuous cycles of soil genesis formed numerous kinds of Mollisols distinguishable largely by differences in parent material, texture, carbonate status, moisture regime, hydrology, and controlled by previous erosion-deposition processes. Therefore, hillslope soils exhibit considerable spatial variability.

Numerous cultivated hillslopes in Iowa are being put into prairie-wetland restoration. Restoration influences the soil quality, nutrient cycling, and C sequestration in these disturbed landscapes. Assessing the spatial variability of these parameters is significant in considering the environmental and ecological functions of the two ecosystems. Systematic and random spatial variability are two kinds of spatial variability. Systematic spatial variability is due to recognizable differences such as lithology, topography, hydrology, and vegetation. Random variation reflect those changes in soil properties that cannot be related to a known cause (Wilding and Drees, 1983).

Numerous studies have examined spatial variability in upland and wetland soils (Gaston et al., 1990; Hayati and Proctor, 1990; Stolt et al., 1993; Stolt et al., 2001; Reese and Moreland, 1996). Stolt et al., (2001) reported soil depth explained most of the total variability in particle size distribution in palustrine wetlands in Virginia, reflecting the alluvial stratification in these systems. They also reported site explained most of the variability in soil chemical properties. Stolt et al., (1993) studied soil variability and parent material uniformity in upland soils in Virginia. They reported landscape position explained the least amount of the variability in soil properties, suggesting horizon differentiation and parent material differences contribute more to soil variability. Gaston et al. (1990) reported the depth to and presence of spodic and argillic horizons varied considerably in uniform flatwood terrains in Florida hosting Aquods, Aquults, Aquents, and Medisaprists. Hammer et al. (1987) reported variability on forested sites in the Mid-Cumberland Plateau in Tennessee was of the order slopes > bottoms > uplands. Reese and Moorland (1996) reported significant differences in organic C and clay content from upland rims to depressional wetlands in a Carolina Bay.

Studies assessing and elucidating soil variability on restored hillslopes and long time monitoring of carbon and soil quality changes on restored Mollisol hillslopes in central Iowa are lacking. The objectives of this study were i.) to assess soil variability in mollic epipedons on restored prairie-wetland hillslopes and ii.) to determine the carbon status on restored prairie-wetland hillslopes for long-term evaluation of C changes in central Iowa.

Materials and Methods

Description of Research Sites and Field Design

Three wetlands were selected on the Des Moines Lobe in central Iowa for detailed study (Figure 1). This region represents the last glacial advance of Late Wisconsinan age and contains young broad, gently rolling, and low-relief landscapes with poorly integrated drainage systems. General stratigraphy of the landscapes includes three strata of surficial sediment over the glacial till. The uppermost two strata represent Late Holocene (4300 YBP) slope alluvium deposited by runoff from adjacent hillslopes (Steinwand and Fenton, 1995). The third strata represent early Holocene slope alluvium derived from the erosion of coarse-textured supraglacial sediments from adjacent hillslopes. Hydrology is characterized as recharge on topographic highs, groundwater flow on sideslopes, and discharge in swales.

Each wetland complex is greater than 100ha in size and is currently managed for wildlife habitat and hunting by the Department of Natural Resources. Each complex varied in restoration time ranging from 5 to 11 years when the study began (Table 1). Research sites also varied slightly in mean total annual precipitation. General landscape zonation consisted of bluestem-switchgrass upland prairies on summits to backslopes and wetland vegetations on footslopes and toeslopes (Figure 2). General wetland zonation included wet prairie (when present)-sedge wetland zone-pond wetland (Tables 2-4). For each wetland complex, transects were conducted on three hillslopes from aerial photographs and soil survey maps. Four groups were assigned in each transect describing vegetative-slope positions interactions:

Group I: upland prairie on summits with moderately well drained soils.

Group II: upland prairies on backslopes with poorly drained soils.

Group III: wet prairies to sedge wetland zones on footslopes with poorly drained calcareous soils.

Group IV: closed pond wetlands on toeslopes with very poorly drained soils.

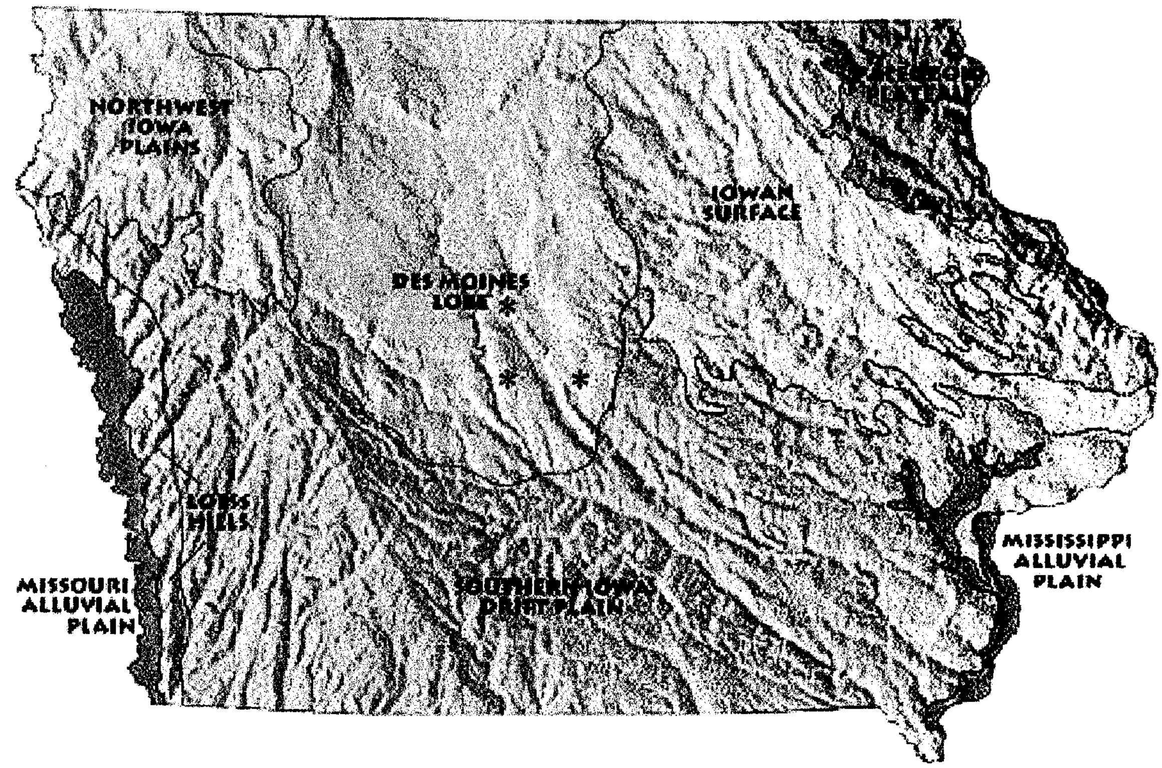

Figure 1. Location of study sites on the Des Moines Lobe.

Table 1. Location, restoration time, and county total precipitation for research sites.

Wetland Complex	County	Location	Yrs Under Restoration up to 2002	Total Annual Precipitation* mm
Gordon's Marsh	Hamilton	T.88N. R.26W. Section 33	11	755
Harrier's Marsh	Boone	T.83.N. R.28.W. Sections 5,8	9	850
Colo Bog	Story	T.84.N. R.21W. Section 11	5	865

* Gordon's Marsh taken from Dideriksen, 1986; Harrier's Marsh: Andrews and Dideriksen, 1981; Colo Bog: DeWitt, 1984.

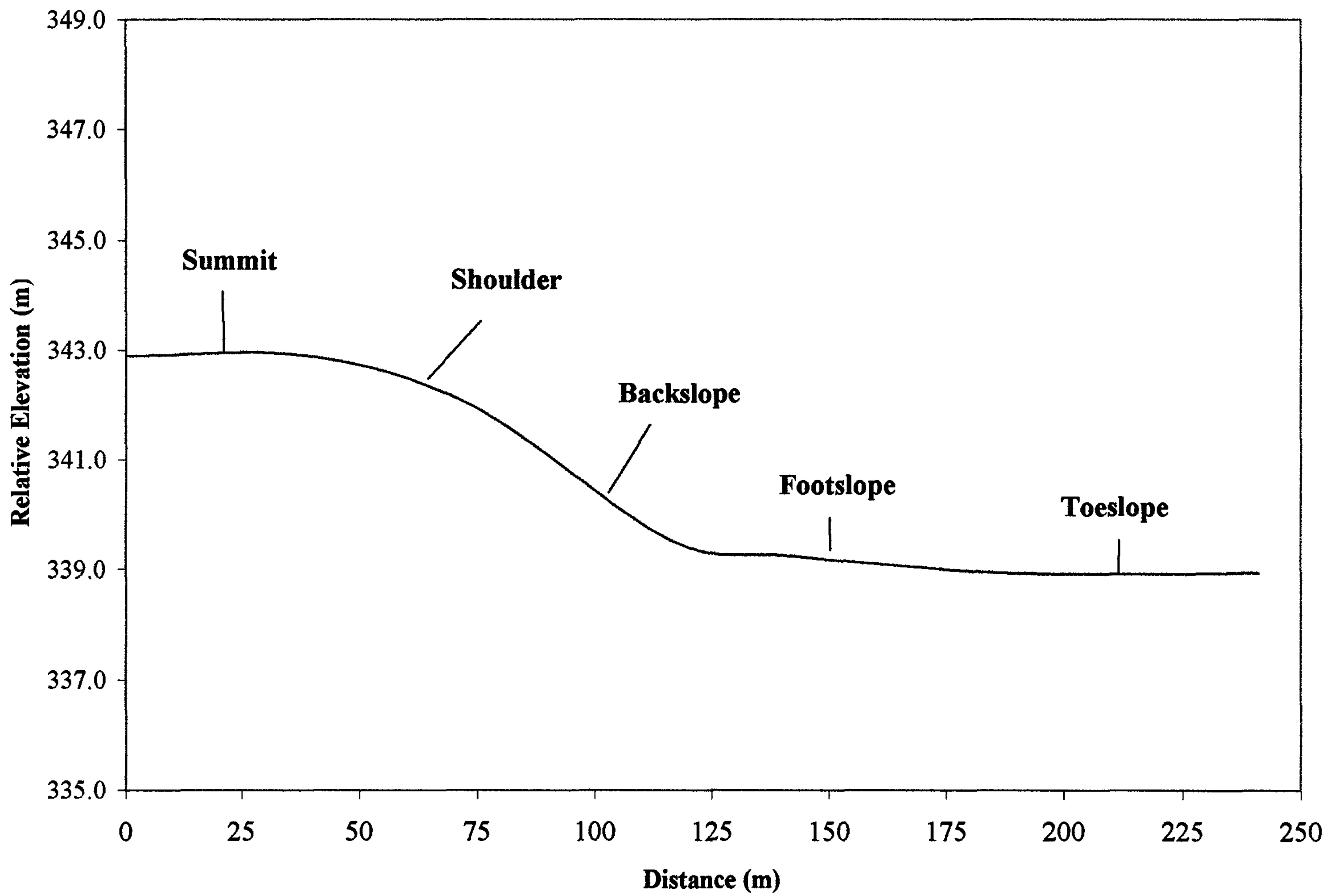

Figure 3. Typical slope profile in a till hillslope.

Table 2. Vegetative zones along restored hillslopes in Colo Bog.

Well	Current Vegetation	Landscape Position	Common Species
			Transect 1
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
6	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
7	Pond Depression	Footslope	*Carex typhina* (cattail sedge)
8	Pond Depression	Toeslope	*Carex typhina* (cattail sedge)
			Transect 2
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Wet Prairie	Footslope	*Aster simplex* (whitefield aster); *Panicum* species
6	Sedge Wetland Pond	Toeslope	*Dulichium arundinaceum* (three-way sedge)
			Transect 3
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Wet Prairie	Footslope	*Panicum* species (switchgrass); *Aster simplex* (whitefield aster); *Asclepsias* sp (milkweed)
5	Wetland Zone	Footslope	*Cyperus* sp. (Flatsedge); *Aster simplex* (whitefield aster); *Scirpus* sp (bulrush)
6	Cattail Wetland Pond	Toeslope	*Carex typhina* (cattail sedge)
7	Wet Prairie	Footslope	*Panicum* species; *Aster simplex* (whitefield aster); *Setaria* sp (foxtail).

Table 3. Vegetative zones along restored hillslopes in Harrier's Marsh.

Plot	Current Vegetation	Landscape Position	Common Species
		Transect 1	
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Wetland Zone	Footslope	*Phalaris arundinacea* (reed canarygrass) and *Carex Typhina* (cattail sedge)
5	Cattail Zone	Footslope	*Carex Typhina* (cattail sedge)
6	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
		Transect 2	
1	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Wetland Zone	Footslope	*Phalaris arundinaceae* (reed canarygrass) and *Carex Typhina* (cattail sedge)
4	Cattail Zone	Footslope	*Carex Typhina* (cattail sedge)
5	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
6	Cattail Zone	Toeslope	*Carex Typhina* (cattail sedge)
7	Cattail Zone	Toeslope	*Carex Typhina* (cattail sedge)
		Transect 3	
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Lower Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Three-way Sedge Zone	Footslope	*Dulichium arundinaceum* (three-way sedge)
6	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (waterhemp)

Table 4. Vegetative zones along restored hillslopes in Gordon's Marsh.

Well	Current Vegetative Use	Landscape Position	Common Species
		Transect 1	
1	Upland Prairie	Summit	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
2	Upland Prairie	Shoulder	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
3	Upland Prairie	Upper Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
4	Upland Prairie	Lower Backslope	*Panicum* species (switchgrass); *Andropogon* species (bluestem)
5	Wet Prairie	Upper Footslope	*Phalaris arundinacea* (Reed Canary Grass); *Aster simplex* (Whitefield aster); *Panicum* species
6	Sedge Zone	Lower Footslope	*Dulichium arundinaceum* (Three-way sedge)
7	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (Waterhemp); and *Setaria* species (Foxtail)
8	Pond Depression	Toeslope	*Polygonum amphibium* (water smartweed); *Amaranthus rudis* (Waterhemp); and *Setaria* species (Foxtail)
		Transect 2	
1	Upland Prairie	Shoulder	*Panicum* species (Switchgrass); *Andropogon* species (Bluestem)
2	Upland Prairie	Backslope	*Panicum* species (Switchgrass); *Andropogon* species (Bluestem)
3	Wet PrairieI	Upper Footslope	*Panicum* species; *Phalaris arundinaceae* (Reed Canarygrass); *Aster simplex* (whitefield aster)
4	Wet PrairieII	Middle Footslope	*Phalaris arundinacea* (Reed Canarygrass); *Panicum* species (switchgrass); *Carex typhina* (Cattail Sedge)
5	Cattail Zone	Lower Footslope	*Carex typhina* (Cattail sedge)
6	Pond Depression	Toeslope	*Eleocharis* species (Spikerush)
		Transect 3	
1	Alfalfa Food Plot	Summit	*Medicago sativa*
2	Mowed Trail	Summit	Mowed trail
3	Oak/Cedar Forest	Backslope	*Quercus* species
4	Bromegrass Prairie	Upper Footslope	*Bromus inermis* (Smooth Bromegrass); *Phalaris arundinacea* (Reed Canarygrass)
5	RCG Pond Depression	Lower Footslope	*Phalaris arundinacea* (Reed Canarygrass)
6	RCG Pond Depression	Toeslope	*Phalaris arundinacea* (Reed Canarygrass)
7	RCG Pond Depression	Toeslope	*Phalaris arundinacea* (Reed Canarygrass)

Soil series and classification for each hillslope are provided in Tables 5-7. Soils were sampled at three depth intervals (0-15, 15-30, 30-45cm) within each group. Water table is present approximately 0-4% of the time from 0-30cm and 0-13% of the time from 30-45cm in the wetland complexes.

Laboratory and statistical methods

Particle size distribution was determined by the pipette method (Walter et al., 1978). Soil pH was determined in a 1:1 soil-water mixture. Total and organic C was measured by dry combustion using a LECO CHN analyzer. Samples were analyzed for extractable Fe and Mn (DTPA extraction), available (Mehlich-3 extraction), extractable Ca, Mg, and K (NH_4Oac extraction), and cation exchange capacity (CEC) (Soil Survey Staff, 1996). Calcium carbonate equivalency (CCE) was determined using the Chittick apparatus (Boellstroff, 1978). Bulk density was determined by the clod method (Soil Survey Staff, 1996).

The nested design was used to estimate the percentage of variability explained by each landscape parameter as (SAS Institute, 1985). The value for a given soil variable for each soil group can be explained by the ideal statistical model:

$$Y_{ijkl} = \mu + S_i + T_{ij} + L_{ijk} + D_{ijkl} + R_{ijklm} \quad [2]$$

where μ represents the population means, S_i the site effects, T_{ij} the transect effects, G_{ijk} the vegetation-slope position effects; D_{ijkl} the soil depth effects, and R_{ijklm} the random error. Systematic variability will be discussed since the variability explained by random effects for our results was <1%.

Results and Discussion

Elucidation of Sources of Soil Variability

Slope position explained most of the systematic variability for sand, fine silt, extractable Ca and Mg, and CEC in upland prairie ecosystems (Table 8). Site explained most of the systematic variability in clay content in these ecosystems. Soil depth explained most of the systematic

Table 5. Soil series and classification along the restored hillslopes in Colo Bog.

Well	Soil Series	Classification	Natural Drainage[1]	Slope Element	Current Ecology
		Transect 1			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	Summit	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWP	Summit	Upland Prairie
3	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Backslope	Upland Prairie
4	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Backslope	Upland Prairie
5	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
6	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Pond Depression
8	Can.-Okoboji	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Very Poor	Toeslope	Pond Depression
		Transect 2			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWP	Shoulder	Upland Prairie
2	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
4	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	Toeslope	Sedge Depression
		Transect 3			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	Shoulder	Upland Prairie
2	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	Backslope	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	Backslope	Upland Prairie
4	Delft-Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	Footslope	Wet Prairie I
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie II
6	Glencoe	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Very Poor	Toeslope	Cattail Depression
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	Footslope	Wet Prairie III

1 = SWP – somewhat poorly drained; MWD = moderately well drained

Table 6. Soil series and classification along the restored hillslopes in Harrier's Marsh.

Well	Soil Series	Classification	Natural Drainage	Slope Element	Current Ecology
		Transect 1			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD[1]	ST[2]	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	SH	Upland Prairie
3	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wetland Zone
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
6	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	TS	Pond Depression
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 2			
1	Crippin	Fine-loamy, mixed, superactive, calcareous, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
2	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
3	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wetland Zone
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
5	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
6	Harps	Fine-loamy, mixed, superactive, mesic Typic Calciaquoll	Poor	TS	Cattail Zone
7	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	TS	Cattail Zone
		Transect 3			
1	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	ST	Upland Prairie
2	Clarion	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	MWD	SH	Upland Prairie
3	Delft	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Sedge Zone
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression

1 = SWP – somewhat poorly drained; MWD = moderately well drained
2 = ST = summit; SH = shoulder; BS = backslope; FS = footslope; TS = toeslope

Table 7. Soil series and classification along the restored hillslopes in Gordon's Marsh.

Well	Soil Series	Classification	Natural Drainage	Slope Element	Current Ecology
		Transect 1			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP[1]	St[2]	Upland Prairie[3]
2	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
3	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
4	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	BS	Upland Prairie
5	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	FS	Wet Prairie
6	Delft T	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll	Poor	FS	Sedge Zone
7	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very poor	TS	Pond Depression
8	Wacousta	Fine-silty, mixed, mesic Typic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 2			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	SH	Upland Prairie
2	Webster	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll	Poor	BS	Upland Prairie
3	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wet Prairie
4	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Wet Prairie
5	Canisteo	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll	Poor	FS	Cattail Zone
6	Okoboji	Fine, smectitic, mesic Cumulic Vertic Endoaquoll	Very Poor	TS	Pond Depression
		Transect 3			
1	Nicollet	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll	SWP	St	Alfalfa food plot
2	Delft T	Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll	Poor	St	Mowed trail
3	Delft	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll	Poor	BS	Oak/cedar forest
4	Canisteo	Fine-loamy, mixed, superactive, calcareous Typic Endoaquoll	Poor	FS	Bromegrass Zone
5	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	FS	RCG Depression
6	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	TS	RCG Depression
7	Klossner	Fine-loamy, mixed, euic, mesic Terric Haplosaprist	Very poor	TS	RCG Depression

T = Taxadjunct.
1 = SWP – somewhat poorly drained.
2 = St – summit; SH – shoulder; BS = Backslope; FS = Footslope; TS = Toeslope.
3 = RCG = Reed Canary Grass.

Table 8. Systematic soil property variability explained by site, transect, slope position, and depth.

Variable	Site	Transect	Slope Position	Depth
Upland Prairies Ecosystems				
Sand	23	15	50	12
Coarse Silt	0	28	28	44
Fine Silt	14	13	52	21
Clay	39	13	18	30
pH	22	39	30	9
Mn	6	10	0	84
Fe	15	34	0	51
Ca	0	8	76	16
Mg	15	16	54	15
K	3	12	0	85
P	0	0	0	100
CEC	0	8	78	14
TC	0	0	42	58
OC	1	0	42	57
Bulk Density	6	0	35	59
Wetland Ecosystems				
Sand	25	0	71	4
Coarse Silt	13	49	19	19
Fine Silt	23	0	69	8
Clay	0	39	55	6
pH	4	0	79	17
Mn	8	0	48	44
Fe	22	0	50	28
Ca	0	39	22	39
Mg	28	53	7	12
K	1	0	31	68
P	0	1	1	98
CEC	0	49	13	38
TC	9	4	17	70
OC	2	3	0	95
Bulk Density	33	0	33	34

variability in coarse silt, extractable Mn, extractable extractable Fe, available K, available P, total C, and organic C in upland prairies. In the wetland ecosystem, transect explained most of the variability in coarse silt, extractable Mg, and CEC. Slope position explained most of the variability in sand, fine silt, clay, pH, extractable Mn, and extractable Fe. Soil depth explained most of the variability in available K, available P, total C, and organic C in the wetland ecosystems. Site, slope position, and soil depth explained approximately 33-34% of the variability in bulk density in the wetlands.

The partitioning of systematic variability differed for each group independently (Table 9). Transect explained most of the systematic variability in sand, fine silt, pH, extractable Fe, extractable Ca, Mg, and CEC in group I soils. Soil depth explained most of this variability in coarse silt, clay, extractable Mn, available K, available P, total C, organic C and bulk density in group I soils. Transect accounted for most of the systematic variability in sand, coarse silt, fine silt, clay, extractable Ca, Mg, and CEC in group II soils. Soil depth explained most of this variability in extractable Mn, extractable Fe, available K, available P, total C, and organic C in group II soils. Site explained 46% of the variability in pH, 40% in clay content, 30% in bulk density, and 29% in extractable Mg for group II soils. Transect explained most of the systematic variability in sand, coarse silt, fine silt, clay, extractable Ca, Mg, and CEC in group III soils. Soil depth explained most of the variability in pH, extractable Mn, extractable Fe, available K, available P, total C, organic C, and bulk density in group III soils. Site accounted for 29% of the variability in coarse silt, 43% in extractable Fe, and 30% in extractable Mn in group III soils and explained for most of the variability in sand and fine silt in group IV soils.

Particle size distribution

Particle size distribution varied on each hillslope in each wetland complex (Tables 10-12). Particle size distribution also varied within each soil group. Soil textures from 0-45cm were clay loams in group I soils in Gordon's Marsh. Soil texture from 0-45cm ranged from loam to clay

Table 9. Systematic soil property variability explained by site, transect, and depth.

Variable	Site	Transect	Depth	Site	Transect	Depth
		Group I			Group II	
Sand	39	49	12	0	90	10
Coarse Silt	0	24	76	0	69	31
Fine Silt	29	58	13	0	72	28
Clay	31	30	39	40	42	18
pH	6	87	7	46	40	14
Mn	3	4	93	7	0	93
Fe	30	49	21	4	17	79
Ca	0	82	18	0	80	20
Mg	0	83	17	29	55	16
K	0	0	100	12	0	88
P	5	0	95	0	0	100
CEC	0	82	18	0	83	17
TC	10	1	89	0	28	72
OC	27	0	73	0	23	77
Bulk density	11	0	89	30	37	33
		Group III			Group IV	
Sand	0	87	13	69	25	6
Coarse Silt	29	58	13	8	70	22
Fine Silt	8	65	27	66	19	15
Clay	0	94	6	12	83	5
pH	0	44	56	9	62	30
Mn	10	0	90	8	44	48
Fe	43	8	49	41	16	43
Ca	0	62	38	3	46	51
Mg	30	65	5	31	48	21
K	0	5	95	0	32	68
P	0	0	100	0	0	100
CEC	0	68	32	0	49	51
TC	4	0	96	4	33	63
OC	10	6	84	3	31	66
Bulk density	11	2	83	57	18	24

Table 10. Particle size distribution and bulk density for each hillslope in Gordon's Marsh.

Group	N	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	Bulk Density $g\ cm^3$
				Transect 1			
I	2	0-15	30	20	23	28	1.20
		15-30	29	17	21	32	1.21
		30-45	26	17	24	33	1.18
II	2	0-15	24	19	25	32	1.15
		15-30	23	18	25	34	1.19
		30-45	20	19	27	34	1.23
III	2	0-15	19	19	25	32	1.07
		15-30	15	18	25	34	1.10
		30-45	17	19	27	34	1.18
IV	2	0-15	4	30	34	32	0.76
		15-30	3	23	39	34	0.97
		30-45	4	21	43	32	0.98
				Transect 2			
I	1	0-15	36	17	20	27	1.23
		15-30	35	18	20	27	1.29
		30-45	33	16	21	30	1.16
II	1	0-15	39	17	17	27	1.16
		15-30	37	16	18	29	1.19
		30-45	36	15	19	30	1.19
III	4	0-15	35	19	21	25	1.21
		15-30	35	18	21	26	1.26
		30-45	35	18	21	26	1.27
IV	1	0-15	11	16	35	38	0.97
		15-30	12	18	35	35	1.15
		30-45	9	17	36	38	1.24
				Transect 3 (drained)			
I	2	0-15	21	22	27	29	1.09
		15-30	22	21	27	30	1.28
		30-45	27	19	24	30	1.21
II	2	0-15	29	21	23	27	1.16
		15-30	29	26	16	29	1.15
		30-45	28	19	24	29	1.17
III	2	0-15	29	22	24	25	1.12
		15-30	35	21	22	22	1.19
		30-45	32	21	22	25	1.29
IV	2	0-15	7	34	25	33	0.82
		15-30	12	29	30	30	0.80
		30-45	10	23	35	32	0.78

Table 11. Particle size distribution and bulk density for each hillslope in Colo Bog.

Group	N	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	Bulk Density $g\ cm^3$
				Transect 1			
I	2	0-15	35	21	26	18	1.19
		15-30	31	20	23	26	1.17
		30-45	29	18	24	28	1.15
II	4	0-15	34	18	20	28	1.19
		15-30	31	17	22	30	1.22
		30-45	33	16	22	29	1.17
IV	2	0-15	36	21	21	22	1.12
		15-30	35	20	22	23	1.37
		30-45	35	20	21	24	1.31
				Transect 2			
I	1	0-15	33	18	21	28	1.16
		15-30	27	18	25	31	1.11
		30-45	27	18	23	32	1.06
II	3	0-15	30	21	23	26	1.18
		15-30	29	19	23	29	1.13
		30-45	28	20	23	29	1.15
III	1	0-15	33	23	20	24	1.35
		15-30	34	22	18	26	1.34
		30-45	34	19	20	27	1.34
IV	1	0-15	15	23	28	34	1.29
		15-30	16	22	27	34	1.37
		30-45	22	20	26	32	1.35
				Transect 3			
I	1	0-15	38	22	18	22	1.13
		15-30	39	20	17	24	1.19
		30-45	40	19	17	24	1.17
II	2	0-15	31	22	22	25	1.28
		15-30	30	22	22	26	1.25
		30-45	30	21	21	28	1.21
III	3	0-15	34	19	20	26	1.21
		15-30	31	18	22	29	1.27
		30-45	31	17	23	29	1.27
IV	1	0-15	37	18	20	25	1.20
		15-30	34	18	21	27	1.28
		30-45	34	17	21	28	1.21

Table 12. Particle size distribution and bulk density for each hillslope in Harrier's Marsh.

Group	N	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	Bulk Density g cm^3
				Transect 1			
I	2	0-15	38	19	19	24	1.15
		15-30	35	19	20	26	1.27
		30-45	28	19	23	30	1.11
II	1	0-15	38	20	18	24	1.32
		15-30	38	21	18	23	1.31
		30-45	35	20	19	26	1.24
III	2	0-15	27	21	24	28	1.00
		15-30	26	22	23	29	1.32
		30-45	27	20	23	30	1.40
IV	2	0-15	15	22	29	33	1.07
		15-30	16	22	30	32	1.27
		30-45	15	21	31	33	1.30
				Transect 2			
I	1	0-15	46	21	14	19	1.11
		15-30	45	17	15	23	1.21
		30-45	44	16	16	24	1.10
II	1	0-15	40	22	16	22	1.25
		15-30	36	24	18	22	1.23
		30-45	34	22	20	24	1.34
III	4	0-15	31	31	21	17	1.07
		15-30	30	31	22	17	1.16
		30-45	38	27	19	16	1.28
IV	1	0-15	14	35	29	22	0.97
		15-30	14	34	30	22	1.01
		30-45	26	30	24	20	1.25
				Transect 3			
I	2	0-15	42	20	17	21	1.12
		15-30	42	19	16	23	1.31
		30-45	42	15	18	25	1.22
II	2	0-15	30	21	23	26	1.21
		15-30	28	20	24	28	1.19
		30-45	26	19	25	30	1.19
III	1	0-15	29	23	22	26	1.21
		15-30	24	24	24	28	1.31
		30-45	29	20	23	28	1.37
IV	2	0-15	15	25	30	31	1.14
		15-30	13	25	31	31	1.19
		30-45	16	24	29	30	1.24

loam in group I soils in Colo Bog. Loam texture dominated the upper 45cm in group I soils in Harrier's Marsh. Group II soils had clay loam textures in Gordon's Marsh but ranged from loam to clay loam in Colo Bog and Harrier's Marsh. The mollic epipedon in group III soils had loam to clay loam textures in all wetland complexes. The mollic epipedon in Group IV soils had silty clay loam textures in Gordon's Marsh. Textures were loam, clay loam, and silty clay loam in Colo Bog and ranged from silt loam to silty clay loam in Harrier's Marsh.

The range in sand content from 0-45cm in Gordon's Marsh was 7-15% in group I soils, 14-16% in group II soils, 16-20% in group III soils, and 6-9% in group IV soils among the three hillslopes. The range in sand content in Colo Bog was 5-13% in group I soils, 2-5% in group II soils, 3-4% in group III soils, and 13-22% in group IV soils among the three hillslopes. The range in sand content from 0-45cm in Harrier's Marsh ranged from 8-16% in group I soils, 9-10% in group II soils, 4-11% in group III soils, and 1-11% in Harrier's Marsh among the hillslopes. Highest variability occurred from 30-45cm in all groups.

The range in coarse silt content from 0-45cm in Gordon's Marsh was 3-5% in group I soils, 4-10% in group II soils, 3% in group III soils, and 6-18% in group IV soils. The range in coarse silt content in Colo Bog was 1-4% in group I soils, 4-6% in group II soils, 3-4% in group III soils, and 3-5% in group IV soils. The range in coarse silt content from 0-45cm in Harrier's Marsh ranged from 2-3% in group I soils, 2-4% in group II soils, 7-10% in group III soils, and 9-13% in group IV soils in Harrier's Marsh. The range in fine silt content from 0-45cm in Gordon's Marsh was 3-7% in group I soils, 8-9% in group II soils, 4-6% in group III soils, and 8-10% in group IV soils. The range in fine silt content in Colo Bog was 7-8% in group I soils, 1-3% in group II soils, 1-4% in group III soils, and 5-8% in group IV soils. The range in fine silt content from 0-45cm in Harrier's Marsh ranged from 5-7% in group I soils, 6-7% in group II soils, 2-4% in group III soils, and 1-7% in Harrier's Marsh.

The range in clay content from 0-45cm in Gordon's Marsh was 2-5% in group I soils, 5% in group II soils, 7-12% in group III soils, and 5-6% in group IV soils. The range in clay content in

Colo Bog was 7-10% in group I soils, 1-4% in group II soils, 4-6% in group III soils, and 8-12% in group IV soils. The range in clay content from 0-45cm in Harrier's Marsh ranged from 3-6% in group I soils, 4-6% in group II soils, 9-14% in group III soils, and 10-13% in Harrier's Marsh. High variability in particle size distribution among groups in each wetland complex generally occurred on footslopes and toeslopes, reflecting the heterogeneity of the hillslope sediments. These soils also are on areas in the landscape that accumulate sediment. Since these hillslope were previously cultivated, the variability also reflects the degree of disturbance from cultivation practices.

Chemical Properties

Tables 13-15 show selected soil chemical properties in all groups on each hillslope per wetland complex. Table 16 shows the mean for each chemical parameter in each wetland complex. Each soil group differed in chemical properties on the restored hillslopes. Each hillslope within each wetland complex also exhibited considerable variability in extractable cations and available nutrients.

Soil pH in group I soils ranged from strongly to moderately acid in Gordon's Marsh, strongly acid to moderately alkaline in Harrier's Marsh, and moderately acid to slightly acid in Colo Bog. Soil pH in group II soils ranged from strongly acid to neutral in Gordon's Marsh, slightly acid to slightly alkaline in Harrier's Marsh, and moderately acid to neutral in Colo Bog. Soil pH in group III soils ranged from neutral to moderately alkaline in all three wetland complexes. Soil pH in group IV soils ranged from slightly acid to neutral in Gordon's Marsh, neutral to slightly alkaline in Harrier's Marsh, and slightly acid to moderately alkaline in Colo Bog. Soil chemical properties in the mollic epipedon also varied considerably among soil groups in each hillslope, within each hillslope in each wetland complex, and among wetland complexes.

The general trend in soil pH per depth interval is:

0-30cm: I < or > II < II > IV
30-45cm: I < II < III > IV

Table 13. Selected soil chemical properties in each depth interval in Gordon's Marsh.

Group	Depth cm	pH	Mn mg kg^{-1}	Fe mg kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	K cmol kg^{-1}	P mg kg^{-1}	CEC cmol kg^{-1}	CCE %
					Transect 1					
I	0-15	5.6	47	73	14.6	3.3	0.7	28	18.6	-
	15-30	5.5	33	61	16.1	3.4	0.3	5	19.9	-
	30-45	5.8	14	40	17.1	4.0	0.3	4	21.4	-
II	0-15	6.4	31	39	27.7	3.6	0.7	45	31.9	-
	15-30	6.6	18	44	31.9	4.0	0.4	20	36.2	-
	30-45	6.7	12	20	33.0	4.9	0.3	8	38.3	-
III	0-15	7.4	16	49	36.6	3.9	0.4	30	40.9	3
	15-30	7.4	14	43	36.3	4.1	0.2	25	40.7	3
	30-45	7.4	8	21	28.2	4.4	0.3	8	32.9	2
IV	0-15	6.9	14	116	31.2	5.5	0.6	49	37.3	3
	15-30	7.0	5	130	32.7	5.2	0.5	42	38.3	6
	30-45	7.2	10	47	23.4	3.3	0.3	6	27.1	14
					Transect 2					
I	0-15	5.6	41	65	14.8	2.0	0.4	18	17.2	-
	15-30	5.6	42	68	14.7	1.9	0.2	12	16.8	-
	30-45	5.8	15	47	14.9	2.0	0.2	5	17.1	-
II	0-15	6.0	44	122	15.9	2.1	0.3	8	18.3	-
	15-30	6.1	26	79	17.1	2.2	0.2	3	19.5	-
	30-45	6.8	15	32	20.4	3.0	0.3	3	23.7	-
III	0-15	7.8	17	54	28.4	1.8	0.3	32	30.5	4
	15-30	7.9	13	52	33.6	1.9	0.2	19	35.8	5
	30-45	8.0	7	21	31.1	2.4	0.2	8	33.8	6
IV	0-15	6.4	27	107	23.4	2.3	0.5	32	26.2	-
	15-30	6.7	25	44	22.4	2.5	0.3	10	25.2	-
	30-45	7.2	17	22	22.3	3.1	0.4	5	25.9	-
					Transect 3 (drained)					
I	0-15	5.4	39	99	16.7	2.0	0.3	17	19.0	-
	15-30	5.8	37	104	19.4	2.3	0.2	7	22.0	-
	30-45	5.9	9	88	17.2	2.6	0.2	4	20.1	-
II	0-15	5.4	41	104	12.7	1.7	0.7	38	15.1	-
	15-30	5.8	34	86	15.2	2.0	0.2	11	17.4	-
	30-45	5.9	23	69	15.6	2.1	0.2	9	17.9	-
III	0-15	7.2	15	29	23.5	1.9	0.4	31	25.9	3
	15-30	7.6	11	24	27.5	2.2	0.2	14	30.0	3
	30-45	7.8	5	12	21.0	2.3	0.2	11	23.6	5
IV	0-15	6.7	13	160	22.8	3.1	0.4	33	26.5	-
	15-30	6.7	8	125	18.7	2.5	0.1	16	21.5	-
	30-45	6.8	6	141	13.5	1.9	0.1	17	15.6	-

Table 14. Selected soil chemical properties along the restored hillslopes in Harrier's Marsh.

Group	Depth cm	pH	Mn mg kg^{-1}	Fe mg kg^{-1}	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	P mg kg^{-1}	CEC cmol kg^{-1}	CCE %
					Transect 1					
I	0-15	6.7	23	47	13.3	4.2	0.5	35	18.0	-
	15-30	6.2	20	62	13.5	3.7	0.2	8	17.5	-
	30-45	6.4	8	42	14.5	3.8	0.2	6	18.7	-
II	0-15	6.9	27	56	20.9	3.8	0.4	26	25.1	3
	15-30	6.6	22	43	25.6	4.2	0.2	11	30.1	2
	30-45	6.8	13	26	24.8	4.6	0.2	6	29.6	3
III	0-15	7.1	24	80	24.1	4.3	0.5	49	28.9	2
	15-30	7.6	13	31	29.5	4.8	0.3	24	34.7	2
	30-45	7.7	10	26	27.2	4.9	0.3	13	32.4	2
IV	0-15	6.7	35	104	22.5	5.4	0.6	51	28.5	-
	15-30	7.1	25	56	22.3	5.3	0.3	23	27.7	-
	30-45	7.1	12	28	21.6	5.1	0.4	7	27.1	-
					Transect 2					
I	0-15	7.7	21	17	17.9	2.4	0.3	13	20.5	3
	15-30	7.7	17	14	25.3	2.2	0.2	5	27.8	3
	30-45	7.9	12	11	29.0	2.0	0.2	5	31.2	5
II	0-15	7.8	12	31	31.9	3.6	0.2	15	35.8	4
	15-30	7.7	11	26	28.9	3.8	0.2	8	32.9	4
	30-45	7.7	4	20	21.2	4.4	0.2	4	25.8	3
III	0-15	7.2	20	67	21.8	4.2	0.4	20	26.5	2
	15-30	7.3	17	70	22.6	4.5	0.2	12	27.4	2
	30-45	7.6	10	37	18.5	4.0	0.2	4	22.8	4
IV	0-15	7.3	18	73	25.9	4.8	0.3	16	31.1	2
	15-30	7.1	19	68	22.4	4.9	0.2	10	27.5	2
	30-45	7.4	13	39	15.3	4.4	0.3	5	20.0	2
					Transect 3					
I	0-15	5.3	41	57	8.6	2.2	0.4	10	11.2	-
	15-30	5.2	40	58	8.6	2.1	0.2	6	10.8	-
	30-45	5.8	25	30	10.4	2.6	0.2	5	13.2	-
II	0-15	6.5	39	92	18.2	3.4	0.4	32	22.1	-
	15-30	6.7	22	49	21.9	3.6	0.2	9	25.7	-
	30-45	6.9	10	35	21.1	4.1	0.2	5	25.4	-
III	0-15	7.7	18	41	31.8	4.4	0.2	14	36.4	3
	15-30	7.8	14	43	32.2	4.8	0.2	8	37.1	3
	30-45	7.8	3	33	24.7	5.3	0.2	4	30.3	2
IV	0-15	7.0	37	88	25.8	4.5	0.7	37	30.9	2
	15-30	7.0	49	66	27.6	4.2	0.4	29	32.3	2
	30-45	7.5	21	56	25.6	4.5	0.3	11	30.5	2

Table 15. Selected soil chemical properties along the restored hillslopes in Colo Bog.

Group	Depth cm	pH	Mn mg kg^{-1}	Fe mg kg^{-1}	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	P mg kg^{-1}	CEC cmol kg^{-1}	CCE %
					Transect 1					
I	0-15	5.8	35	77	13.3	3.3	0.4	47	17.0	-
	15-30	6.0	35	65	14.1	3.6	0.2	9	17.9	-
	30-45	5.9	19	54	14.1	4.1	0.2	7	18.5	-
II	0-15	5.6	41	85	12.7	2.9	0.4	23	16.0	-
	15-30	5.9	19	67	16.1	3.5	0.2	5	19.8	-
	30-45	6.3	10	46	15.7	3.9	0.2	5	19.8	-
IV	0-15	7.7	12	34	26.9	3.0	0.3	28	30.1	5
	15-30	7.8	10	24	26.1	3.4	0.2	21	29.7	7
	30-45	7.9	13	31	26.4	3.1	0.2	17	29.8	6
					Transect 2					
I	0-15	6.1	26	40	12.5	3.9	0.5	35	16.9	-
	15-30	6.3	21	56	12.2	3.2	0.2	7	15.7	-
	30-45	6.3	13	38	12.1	3.3	0.2	5	15.6	-
II	0-15	6.2	33	78	15.8	4.4	0.4	44	20.7	-
	15-30	6.2	19	55	18.4	4.3	0.2	7	22.9	-
	30-45	6.4	12	33	17.7	4.4	0.2	5	22.4	-
III	0-15	7.5	16	17	27.1	5.4	0.3	27	32.9	2
	15-30	7.8	9	8	27.3	5.3	0.2	4	32.9	2
	30-45	7.7	6	6	23.6	5.8	0.2	4	29.7	2
IV	0-15	6.5	38	94	25.0	3.9	0.5	72	29.4	-
	15-30	6.7	28	26	29.0	4.7	0.4	35	34.2	-
	30-45	6.9	16	18	23.5	4.6	0.3	15	28.5	-
					Transect 3					
I	0-15	6.4	33	58	15.6	2.4	0.4	34	18.5	-
	15-30	6.5	9	57	16.9	3.2	0.2	5	20.4	-
	30-45	6.4	12	45	15.4	3.4	0.2	4	19.0	-
II	0-15	6.1	38	92	19.2	4.5	0.4	36	24.1	-
	15-30	6.3	26	56	23.5	5.3	0.2	7	29.0	-
	30-45	6.6	14	17	21.1	5.3	0.2	5	26.6	-
III	0-15	7.6	15	19	30.2	3.1	0.3	29	33.7	5
	15-30	7.8	8	11	30.0	3.2	0.2	7	36.7	7
	30-45	7.9	4	5	28.8	3.4	0.2	4	32.4	7
IV	0-15	7.7	18	29	31.4	2.6	0.3	39	34.4	5
	15-30	7.3	19	28	31.5	3.0	0.2	13	34.7	3
	30-45	7.3	16	13	25.4	3.5	0.2	6	29.2	3

Table 16. Selected mean soil chemical properties along each wetland complex.

Group	Depth cm	pH	Mn mg kg^{-1}	Fe mg kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	K cmol kg^{-1}	P mg kg^{-1}	CEC cmol kg^{-1}	CCE %
					Colo Bog					
I	0-15	6.0	31	58	13.8	3.2	0.4	39	17.5	-
	15-30	6.2	22	59	14.4	3.3	0.2	7	18.0	-
	30-45	6.1	15	46	13.9	3.6	0.2	5	17.7	-
II	0-15	5.9	37	85	15.9	3.9	0.4	34	20.3	-
	15-30	6.1	21	59	19.3	4.4	0.2	6	23.9	-
	30-45	6.4	12	32	18.2	4.5	0.2	5	22.9	-
III	0-15	7.5	16	18	28.7	4.3	0.3	28	33.3	4
	15-30	7.8	9	10	28.7	4.3	0.2	6	34.8	5
	30-45	7.8	5	6	26.2	4.6	0.2	4	31.1	5
IV	0-15	6.9	23	52	27.8	3.2	0.4	46	31.3	3
	15-30	7.1	19	26	28.9	3.7	0.3	23	32.9	3
	30-45	7.2	15	21	25.1	3.7	0.2	13	29.2	3
					Harrier's Marsh					
I	0-15	5.8	28	40	13.3	2.9	0.4	19	16.6	1
	15-30	5.6	26	45	15.8	2.7	0.2	6	18.7	1
	30-45	6.2	15	28	18.0	2.8	0.2	5	21.0	1
II	0-15	6.8	26	60	23.7	3.6	0.3	24	27.7	2
	15-30	6.8	18	39	25.5	3.9	0.2	9	29.6	2
	30-45	7.0	9	27	22.4	4.4	0.2	5	26.9	2
III	0-15	7.3	21	63	25.9	4.3	0.4	28	30.6	2
	15-30	7.5	15	48	28.1	4.6	0.2	15	33.1	2
	30-45	7.7	8	32	23.5	4.7	0.2	7	28.5	2
IV	0-15	6.9	30	88	24.7	4.9	0.5	35	30.2	1
	15-30	7.1	31	63	24.1	4.8	0.3	21	29.2	1
	30-45	7.3	15	41	20.8	4.7	0.3	8	25.9	1
					Gordon's Marsh					
I	0-15	5.6	44	69	14.7	2.7	0.6	23	17.9	-
	15-30	5.6	38	65	15.4	2.7	0.3	9	18.4	-
	30-45	5.8	15	44	16.0	3.0	0.3	5	19.3	-
II	0-15	6.2	38	81	21.8	2.9	0.5	27	25.1	-
	15-30	6.3	22	62	24.5	3.1	0.3	12	27.9	-
	30-45	6.7	14	26	26.7	4.0	0.3	6	31.0	-
III	0-15	7.6	17	52	32.5	2.9	0.4	31	35.7	4
	15-30	7.6	14	48	35.0	3.0	0.2	22	38.3	4
	30-45	7.6	8	21	29.7	3.4	0.3	8	33.4	5
IV	0-15	6.6	21	112	27.3	3.9	0.6	41	31.8	-
	15-30	6.8	15	87	27.6	3.9	0.4	26	31.8	-
	30-45	7.2	14	35	22.9	3.2	0.4	6	26.5	7

The general group trend in extractable Mn chemical properties is:

0-15cm: $I = II > III \leq IV$
15-45cm: $I \geq II > III < IV$

The general trend in Extractable Fe per depth interval is:

0-15cm: $I < II > III < IV$
15-45cm: $I \geq II > III < IV$

The general trend in extractable Ca per depth interval is:

0-45cm: $I < II < III \geq IV$

The general trend in extractable Mg per depth interval is:

0-15cm: $I < II \leq III$ < or > IV
15-30cm: $I < II$ < or > III < or > IV
30-45cm: $I < II$ < or > III ≤ or ≥ IV

The general trend in available K per depth interval is:

0-15cm: $I \geq II$ < or > $III < IV$
15-30cm: $I = II \geq III < IV$
30-45cm: $I = II = III \leq IV$

The general trend in available P per depth interval is:

0-15cm: I > or < II > or < $III < IV$
15-30cm: I > or < $II \leq III < IV$
30-45cm: $I \leq II$ > or < III < or > IV

The general trend in CEC per depth interval is:

0-45cm: $I < II < III > IV$

No general trend in pH and available P was observed between groups I and II soils from 0-15cm. In general, group I soils had greater available K contents from 0-15cm than group II soils. Group I soils also had lower extractable Fe, extractable Ca, Mg, CEC and similar extractable Mn contents as compared to group II soils from 0-15cm. Group I soils had equal or greater extractable Mn and Fe contents from 15-30 and 30-45cm than group II soils. Group I soils had lower pH, extractable Ca, Mg, CEC and similar available K contents with group II soils from 15-30 and 30-

45cm. No trend in available K and P was observed between group II and III soils from 0–15cm. No general trend in extractable Mg was observed between group II and III soils from 15-30cm and in available P from 30-45cm. Group II soils had lower pH, extractable Ca, Mg, and CEC from 0-15cm than group III soils. Group II soils also had higher extractable Mn and Fe contents than group III soils from 0-15cm. Group II soils had lower pH, extractable Ca, available P, and CEC than group III soils from 15-30cm. Group II soils had lower pH, extractable Ca, and CEC than group III soils from 30-45cm. Group II and III soils had similar available K at this depth interval. No general trend in extractable Mg was observed between group III and IV soils from 0-15, 15-30 and 30-45cm. No general trend in available P was observed between these two groups from 30-45cm. In general, group III soils had higher pH, extractable Ca, and CEC than group IV soils from 0-45cm. Group III soils had lower extractable Mn, extractable Fe, available K, and available P than group IV soils from 0-45.

Since recharge is the dominant process on topographic highs, the soils are leached. This explains the lower pH, extractable cations, and available nutrients in group I soils. Group III and IV soils occur on areas along landscape that accumulate sediment and retain moisture. Landscape position and soil conditions, such as anaerbiosis, favor accumulation of organic matter, fine sediment, and nutrients in these soils. Increased wetness will produce thicker mollic epipedons. Group III soils occur on the rim of the closed depressions. The mollic epipedons have the highest pH, extractable cations, and CCE. The vegetation and near-surface water tables enhances evapotranspiration of water from the soil than water that moves downward in the soil. This results in reversal of leaching where dissolved solids are transferred from the hillslope and the wetland to the edge and concentrated by evapotranspiration (Thompson and Bell, 2000).

Considerable variability in soil chemical properties existed within each wetland complex and among each wetland complex. The range in pH from 0-45cm was 0.1-0.3 units in group I soils, 0.8-1.0 units in group II soils, 0.5-0.6 units in group III soils, and 0.3-0.5 units in group IV soils in Gordon's Marsh. The range in pH from 0-45cm was 2.1-2.5 units in group I soils, 0.9-1.3 units in group II soils, 0.2-0.5 units in group III soils, and 0.1-0.6 units in group IV soils in Harrier's Marsh. The range in pH from 0-45cm was 0.4-0.6 units in group I soils, 0.3-0.5 units in group II soils, 0.0-0.2 units in group III soils, and 1.0-1.2 units in group IV soils in Colo Bog.

The range in extractable Mn from 0-45cm was 6-9 mg kg^{-1} in group I soils, 11-13 mg kg^{-1} in group II soils, 2-3 mg kg^{-1} in group III soils, and 11-20 mg kg^{-1} in group IV soils in Gordon's Marsh. The highest variability in extractable Mn occurred from 15-30cm in group II and IV soils in this site. The range in extractable Mn from 0-45cm was 7-26 mg kg^{-1} in group I soils, 4-8 mg kg^{-1} in group II soils, 2-9 mg kg^{-1} in group III soils, and 3-20 mg kg^{-1} in group IV soils in Colo Bog. The highest variability in extractable Mn occurred from 15-30cm in group I soils and from 0-15 and 15-30cm in group IV soils in Colo Bog. The range in extractable Mn from 0-45cm was 17-23 mg kg^{-1} in group I soils, 9-27 mg kg^{-1} in group II soils, 3-7 mg kg^{-1} in group III soils, and 9-30 mg kg^{-1} in group IV soils in Harrier's Marsh. High variability in extractable Mn occurred in all depth intervals in group I soils and from 15-30 cm in group II and IV soils. Group III soils exhibited lowest variability in extractable Mn in each wetland complex.

The range in extractable Fe from 0-45cm was 34-48 mg kg^{-1} in group I soils, 42-83 mg kg^{-1} in group II soils, 9-28 mg kg^{-1} in group III soils, and 53-119 mg kg^{-1} in group IV soils in Gordon's Marsh. The lowest variability occurred from 30-45cm in group III soils in this wetland complex. The range in extractable Fe from 0-45cm was 31-48 mg kg^{-1} in group I soils, 15-61 mg kg^{-1} in group II soils, 11-39 mg kg^{-1} in group III soils, and 12-31mg kg^{-1} in group IV soils in Harrier's Marsh. Lowest variability in extractable Fe occurred from 30-45cm in group II and III soils and from 15-30cm in group IV soils. The range in extractable Fe from 0-45cm was 9-37 mg kg^{-1} in group I soils, 12-29 mg kg^{-1} in group II soils, 16-26 mg kg^{-1} in group III soils, and mg kg^{-1} in group IV soils in Colo Bog. Low variability occurred from 15-30cm in group I soils, 0-45cm in group II soils, and 15-30cm in group IV soils.

The range in extractable Ca from 0-45cm was 2.1-4.7 cmol kg^{-1} in group I soils, 15.0-17.4 cmol kg^{-1} in group II soils, 8.8-13.1 cmol kg^{-1} in group III soils, and 8.4-14.0 cmol kg^{-1} in group IV soils in Gordon's Marsh. The range in extractable Ca from 0-45cm was 9.3-18.6 cmol kg^{-1} in group I soils, 3.6-13.7 cmol kg^{-1} in group II soils, 8.7-10.0 cmol kg^{-1} in group III soils, and 3.3-10.3 cmol kg^{-1} in group IV soils in Harrier's Marsh. Low variability in extractable Ca occurred from 30-45cm in group II soils and from 0-15cm in group IV soils. The range in extractable Ca from 0-45cm was 3.1-4.7 cmol kg^{-1} in group I soils, 5.4-7.4 cmol kg^{-1} in group II soils, 3.3-5.2 cmol kg^{-1} in group III soils, and 2.9-6.4 cmol kg^{-1} in group IV soils in Colo Bog.

The range in extractable Mg from 0-45cm was 1.3-2.0 cmol kg^{-1} in group I soils, 1.9-2.8 cmol kg^{-1} in group II soils, 2.1-2.2 cmol kg^{-1} in group III soils, and 1.4-3.2 cmol kg^{-1} in group IV soils in Gordon's Marsh. High variability in extractable Mg occurred from 30-45cm in group I and II soils and from 0-15 and 15-30cm in group IV soils. The range in extractable Mg from 0-45cm was 1.6-2.0 cmol kg^{-1} in group I soils, 0.4-0.6 cmol kg^{-1} in group II soils, 0.2-1.3 cmol kg^{-1} in group III soils, and 0.7-1.1 cmol kg^{-1} in group IV soils in Harrier's Marsh. The range in extractable Mg from 0-45cm was 0.4-1.5 cmol kg^{-1} in group I soils, 1.4-1.8 cmol kg^{-1} in group II soils, 2.1-2.7 cmol kg^{-1} in group III soils, and 1.3-1.7 cmol kg^{-1} in group IV soils in Colo Bog. Low variability in extractable Mg occurred from 15-30 and 30-45cm in group I soils in this wetland site.

The range in available K from 0-45cm was 0.1-0.4 cmol kg^{-1} in group I and II soils, 0.0-0.1 cmol kg^{-1} in group III soils, and 0.2-0.4 cmol kg^{-1} in group IV soils in Gordon's Marsh. The range in available K from 0-45cm was 0.0-0.2 cmol kg^{-1} in group I and II soils, 0.1-0.3 cmol kg^{-1} in group III soils, and 0.1-0.4 cmol kg^{-1} in group IV soils in Harrier's Marsh. Highest variability occurred from 0-15cm in all groups in Harrier's Marsh. The range in available K from 0-45cm was 0.0-01 cmol kg^{-1} in group I soils, 0.0 cmol kg^{-1} in group II and III soils, and 0.1-0.2 cmol kg^{-1} in group IV soils in Gordon's Marsh.

The range in available P from 0-45cm was 1-11 mg kg^{-1} in group I soils, 6-37 mg kg^{-1} in group II soils, 2-9 mg kg^{-1} in group III soils, and 12-32 mg kg^{-1} in group IV soils in Gordon's Marsh. Lowest variability in available P occurred from 30-45cm in all groups in Gordon's Marsh. The range in available P from 0-45cm was 1-25 mg kg^{-1} in group I soils, 2-17 mg kg^{-1} in group II soils, 9-35 mg kg^{-1} in group III soils, and 6-35 mg kg^{-1} in group IV soils in Harrier's Marsh. Lowest variability in available P occurred from 15-30 and 30-45cm in group I and II soils and from 30-45cm in group III and IV soils in Harrier's Marsh. The range in available P from 0-45cm was 3-13 mg kg^{-1} in group I soils, 0-21 mg kg^{-1} in group II soils, 2-17 mg kg^{-1} in group III soils, and 11-44 mg kg^{-1} in group IV soils in Gordon's Marsh. Lowest variability in available P occurred from 15-45cm in group I and II soils, 0-15cm in group III soils, and 30-45cm in Group IV soils in Colo Bog.

The range in CEC from 0-45cm was 1.8-5.2 cmol kg^{-1} in group I soils, 16.8-20.4 cmol kg^{-1} in group II soils, 10.2-15.0 cmol kg^{-1} in group III soils, and 11.1-16.8 cmol kg^{-1} in group IV soils in Gordon's Marsh. The range in CEC from 0-45cm was 9.3-18.0 cmol kg^{-1} in group I soils, 4.2-13.7 cmol kg^{-1} in group II soils, 7.5-9.9 cmol kg^{-1} in group III soils, and 2.6-10.5 cmol kg^{-1} in group IV soils in Harrier's Marsh. The range in CEC from 0-45cm was 1.6-4.7 cmol kg^{-1} in group I soils, 6.8-9.2 cmol kg^{-1} in group II soils, 2.7-7.0 cmol kg^{-1} in group III soils, and 1.3-5.0 cmol kg^{-1} in group IV soils in Colo Bog. No trend in the range was observed in this wetland complex. Lowest variability occurred from 0-15cm in group I soils, 0-15 and 30-45cm in group III soils, and from 30-45cm in group IV soils.

The trend in variability in pH per depth in each wetland site is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	II > III > IV > I	0-15cm	I > II > IV > III	0-15cm	IV > I > II > III
15-30cm	II > III > IV = I	15-30cm	I > II > III > IV	15-30cm	IV > I > II > III
30-45cm	II > III > IV > I	30-45cm	I > II > IV > III	30-45cm	IV > I > II > III

The trend in variability in extractable Mn per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	IV > II > I > III	0-15cm	II > I > IV > III	0-15cm	IV > I > II > III

15-30cm	IV > II > I > III	15-30cm	IV > I > II > III	15-30cm	I > IV > II > III
30-45cm	IV = II > I > III	30-45cm	I > IV = II > III	30-45cm	III > I > II > IV

The trend in variability in extractable Fe per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	II > IV > I > III	0-15cm	II > I > III > IV	0-15cm	IV > I > III > II
15-30cm	IV > I > II > III	15-30cm	I > III > II > IV	15-30cm	III > II > I > IV
30-45cm	IV > II > I > III	30-45cm	I > IV > II > III	30-45cm	II > III > IV > I

The trend in variability in extractable Ca per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	II > III > IV > I	0-15cm	II > III > I > IV	0-15cm	II > IV > III > I
15-30cm	II > IV > III > I	15-30cm	I > III > II > IV	15-30cm	II > IV > I > III
30-45cm	II > III > IV > I	30-45cm	I > IV > III > II	30-45cm	II > III > IV > I

The trend in variability in extractable Mg per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	IV > III > II > I	0-15cm	I > IV > II > III	0-15cm	III > II > I > IV
15-30cm	IV > III > II > I	15-30cm	I > IV > II > III	15-30cm	III > II > IV > I
30-45cm	II > I > III > IV	30-45cm	I > III > IV > II	30-45cm	III > IV > II > I

The trend in variability in available K per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	I = II > IV > III	0-15cm	IV > III > I = II	0-15cm	IV > I > II = III
15-30cm	IV > II > I > III	15-30cm	IV > III > I = II	15-30cm	IV > I = II = III
30-45cm	IV > I = II = IV	30-45cm	III = IV > I = II	30-45cm	IV > I = II = III

The trend in variability in CEC per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	II > III > IV > I	0-15cm	II > III > I > IV	0-15cm	II > IV > III > I
15-30cm	II > IV > III > I	15-30cm	I > III > II > IV	15-30cm	II > III > IV > I
30-45cm	II > IV > III > I	30-45cm	I > IV > III > II	30-45cm	II > I > III > IV

The trend in variability in available P per depth for each wetland complex is the following:

Gordon's Marsh		Harrier's Marsh		Colo Bog	
0-15cm	II > IV > I > III	0-15cm	III = IV > I > II	0-15cm	IV > II > I > III
15-30cm	IV > II > III > I	15-30cm	IV > III > I = II	15-30cm	IV > III > I > II
30-45cm	IV > II > III > I	30-45cm	III > IV > II > I	30-45cm	III > IV > I > II

The landscape variability in soil chemical properties in the mollic epipedon differed in each wetland complex. The highest variability in pH from 0-45cm was found in group II soils in Gordon's

Marsh, group I soils in Harrier's Marsh, and group IV soils in Colo Bog. The lowest variability in pH was in group I soils in Gordon's Marsh, group III and IV soils in Harrier's Marsh, and group III soils in Colo Bog. The highest variability in extractable Mn was in group IV soils in Gordon's Marsh. Extractable Mn variability differed for each depth interval in the mollic epipedon in Harrier's Marsh and Colo Bog. High variability in extractable Fe from 0-15cm occurred in group II soils in Gordon's and Harrier's Marsh. High variability in extractable Fe from 15-45cm occurred in group IV soils in Gordon's Marsh and group I soils in Harrier's Marsh. Extractable Fe variability differed for each depth interval in Colo Bog.

Highest variability in extractable Ca from 0-45cm occurred in group II soils in Gordon's Marsh and Colo Bog. Highest variability in extractable Ca from 0-15cm occurred in group II soils and in group I soils from 15-45cm in Harrier's Marsh. Low variability in extractable Ca occurred in group I soils from 0-45cm in Gordon's Marsh. Low variability in extractable Ca occurred in group IV soils from 0-30cm and in group II soils from 30-45cm in Harrier's Marsh. Low extractable Ca variability occurred in group I soils from 0-15cm and 30-45cm and in group III soils from 15-30cm in Colo Bog.

High variability in extractable Mg occurred in group IV soils from 0-30cm and group II soils from 30-45cm in Gordon's Marsh. High variability in extractable Mg from 0-45cm occurred in group I soils in Harrier's Marsh and group III soils in Colo Bog. Low extractable Mg variability in extractable Mg occurred in group I soils from 0-30cm and in group IV soils from 30-45cm in Gordon's Marsh. Low extractable Mg variability occurred in group III soils from 0-30cm and in group II soils from 30-45cm in Harrier's Marsh. Low extractable Mg variability occurred in group IV soils from 0-15cm and in group I soils from 15-45cm in Colo Bog.

High variability in available K occurred in group I soils from 0-15cm and in group IV soils from 15-30cm in Gordon's Marsh. High variability in available K occurred in group IV soils from 0-30cm and in group III soils from 30-45cm. High variability in available K occurred in group IV soils from 0-45cm in Colo Bog. Low variability in available K occurred in group III soils from 0-30cm and in group IV soils from 30-45cm in Gordon's Marsh. Low variability in available K from 0-45cm occurred in group II soils in Harrier's Marsh and in group III soils in Colo Bog. High variability in available P occurred in group II soils from 0-15cm and in group IV soils from 15-45cm in Gordon's Marsh. High variability in available P occurred in group III soils from 0-15 and 30-45cm and in group IV soils from 15-30cm in Harrier's Marsh. High variability in available P occurred in group IV soils from 0-30cm and in group III soils from 30-45cm in Colo Bog. Low variability in available P occurred in group III soils from 0-15cm and in group I soils from 15-45cm in Gordon's Marsh. Low variability in available P occurred in group II soils from 0-30cm and group I soils from 30-45cm in Harrier's Marsh. Low variability in available P occurred in group III soils from 0-15cm and group II soils from 15-45cm in Colo Bog.

Total and Organic Carbon

A common view of restoration is that it influences the nutrient cycling and soil quality of cultivated landscapes. Soil C is considered an important indicator of soil quality. It also is critical in global warming. Little information exists relating the variability of organic C and total C on restored till landscapes in Iowa. Carbon fractions are best expressed on a mass basis. This study developed reference points for future monitoring and assessing the variability of soil C on restored landscapes, within vegetative zones, and among wetland sites. Each hillslope in each wetland complex varied in total and organic C amounts (Tables 17-19). Each soil group varied in mean total and organic C within each wetland complex (Table 20). Considerable variability existed among each hillslope within each wetland complex. In general, total and organic C decreased with depth.

Table 17. Soil carbon amounts along the restored hillslopes in Gordon's Marsh.

Group	Depth cm	OC $g\ m^2$	IC $g\ m^2$	TC $g\ m^2$
		Transect 1		
I	0-15	4810	-	4810
	15-30	4352	-	4352
	30-45	3436	-	3436
	Total	12598	-	12598
II	0-15	6620	-	6620
	15-30	6558	-	6558
	30-45	5430	-	5430
	Total	18608	-	18608
III	0-15	9411	577	9988
	15-30	9649	593	10242
	30-45	5034	470	5504
	Total	24094	1640	25734
IV	0-15	11131	-	11131
	15-30	8525	1147	9672
	30-45	3654	2792	6446
	Total	23310	3939	27249
		Transect 2		
I	0-15	4345	-	4345
	15-30	4249	-	4249
	30-45	3184	-	3184
	Total	11778	-	11778
II	0-15	4323	-	4323
	15-30	3998	-	3998
	30-45	2672	-	2672
	Total	10993	-	10993
III	0-15	5795	992	6787
	15-30	5374	1125	6499
	30-45	3085	1335	4420
	Total	14254	3452	17706
IV	0-15	7657	-	7657
	15-30	3899	328	4226
	30-45	2251	502	2753
	Total	13807	830	14637
		Transect 3		
I	0-15	4169	-	4169
	15-30	4542	-	4542
	30-45	2995	-	2995
	Total	11706	-	11706
II	0-15	5135	-	5135
	15-30	4751	-	4751
	30-45	4414	-	4414
	Total	14300	-	14300
III	0-15	6185	620	6806
	15-30	5807	623	6430
	30-45	2385	1124	3509
	Total	14377	2367	16745
IV	0-15	14293	-	14293
	15-30	13138	-	13138
	30-45	7537	-	7537
	Total	34968	-	34968

Table 18. Soil carbon amounts along the restored hillslopes in Harrier's Marsh.

Group	Depth cm	OC g m^2	IC g m^2	TC g m^2
		Transect 1		
I	0-15	3844	-	3844
	15-30	3793	-	3793
	30-45	2859	-	2859
	Total	10496	-	10496
II	0-15	5326	-	5326
	15-30	4228	-	4228
	30-45	3378	-	3378
	Total	12932	-	12932
III	0-15	4961	517	5478
	15-30	5253	1041	6294
	30-45	4324	839	5163
	Total	16935	2397	16935
IV	0-15	6506	-	6506
	15-30	6392	360	6752
	30-45	4148	391	4539
	Total	17046	751	17797
		Transect 2		
I	0-15	3166	530	3696
	15-30	3703	581	4283
	30-45	2756	990	3746
	Total	9625	2101	11725
II	0-15	5588	956	6544
	15-30	5620	832	6452
	30-45	3551	582	4133
	Total	14759	2370	17129
III	0-15	7931	460	8391
	15-30	8342	418	8760
	30-45	3414	941	4355
	Total	19687	1819	21506
IV	0-15	8701	349	9050
	15-30	8563	407	8970
	30-45	3855	505	4360
	Total	21119	1261	22380
		Transect 3		
I	0-15	2861	-	2861
	15-30	2878	-	2878
	30-45	2079	-	2079
	Total	7818	-	7818
II	0-15	5743	-	5743
	15-30	4834	-	4834
	30-45	3736	-	3736
	Total	14313	-	14313
III	0-15	6176	725	6901
	15-30	7133	668	7801
	30-45	4076	494	4570
	Total	17385	1887	19272
IV	0-15	9372	272	9644
	15-30	7103	374	7477
	30-45	5092	399	5491
	Total	21567	1045	22612

Table 19. Soil carbon amounts along the restored hillslopes in Colo Bog.

Group	Depth cm	OC $g\ m^2$	IC $g\ m^2$	TC $g\ m^2$
		Transect 1		
I	0-15	4966	-	4966
	15-30	4114	-	4114
	30-45	3208	-	3208
	Total	12288	-	12288
II	0-15	4663	-	4663
	15-30	3849	-	3849
	30-45	2524	-	2524
	Total	11036	-	11036
IV	0-15	4704	921	5625
	15-30	3845	1640	5485
	30-45	4130	1363	5493
	Total	12679	3924	16603
		Transect 2		
I	0-15	4532	-	4532
	15-30	3763	-	3763
	30-45	3023	-	3023
	Total	11318	-	11318
II	0-15	5790	-	5790
	15-30	4550	-	4550
	30-45	3360	-	3360
	Total	13700	-	13700
III	0-15	6735	385	7120
	15-30	4245	481	4726
	30-45	2147	381	2528
	Total	13127	1247	14374
IV	0-15	7922	-	7922
	15-30	8102	-	8102
	30-45	4078	-	4078
	Total	20102	-	20102
		Transect 3		
I	0-15	4712	-	4712
	15-30	3413	-	3413
	30-45	2615	-	2615
	Total	10740	-	10740
II	0-15	6079	-	6079
	15-30	5019	-	5019
	30-45	3116	-	3116
	Total	14214	-	14214
III	0-15	5756	2131	7857
	15-30	3940	1569	5509
	30-45	1902	1562	3464
	Total	11598	5262	16860
IV	0-15	5353	1096	6449
	15-30	5251	556	5807
	30-45	3326	633	3959
	Total	13930	2285	16215

Table 20. Mean soil C amounts along undrained hillslopes for each wetland site.

Group	Depth cm	OC g m^2	IC g m^2	TC g m^2
		Colo Bog		
I	0-15	4737	-	4737
	15-30	3763	-	3763
	30-45	2949	-	2949
	Total	11449	-	11449
II	0-15	5511	-	5511
	15-30	4473	-	4473
	30-45	3000	-	3000
	Total	12984	-	12984
III	0-15	6246	1258	7504
	15-30	4093	1025	5118
	30-45	2025	972	2997
	Total	12363	3255	15619
IV	0-15	5993	671	6664
	15-30	5733	732	6465
	30-45	3845	665	4510
	Total	15571	2068	17639
		Harrier's Marsh		
I	0-15	3290	-	3290
	15-30	3458	-	3458
	30-45	2565	-	2565
	Total	9313	-	9313
II	0-15	5522	-	5522
	15-30	4894	-	4894
	30-45	3555	-	3555
	Total	13971	-	13971
III	0-15	6356	567	6923
	15-30	6909	709	7618
	30-45	3938	758	4696
	Total	17203	2034	19237
IV	0-15	8193	207	8400
	15-30	7353	380	7733
	30-45	4365	432	4797
	Total	19911	1019	20930
		Gordon's Marsh		
I	0-15	4578	-	4578
	15-30	4301	-	4301
	30-45	3310	-	3310
	Total	12189	-	12189
II	0-15	5472	-	5472
	15-30	5278	-	5278
	30-45	4051	-	4051
	Total	14801	-	14801
III	0-15	7603	785	8388
	15-30	7512	859	8371
	30-45	4060	903	4963
	Total	19175	2547	21722
IV	0-15	9394	-	9394
	15-30	6212	738	6950
	30-45	2953	1647	4600
	Total	18559	2385	20944

The general trend in total C for each wetland complex based on mean contents is:

Colo Bog:

0-15cm: I < II < III > IV
15-30cm: I < II < III < IV
30-45cm: I < II = III < IV
0-45cm: I < II < III < IV

Harrier's Marsh:

0-15cm: I < II < III < IV
15-30cm: I < II < III < IV
30-45cm: I < II < III < IV
0-45cm: I < II < III < IV

Gordon's Marsh:

0-15cm: I < II < III < IV
15-30cm: I < II < III > IV
30-45cm: I < II < III > IV
0-45cm: I < II < III > IV

Overall:

0-15cm: I < II < III < or > IV
15-30cm: I < II < III < or > IV
30-45cm: I < II ≤ III < or > IV
0-45cm: I < II < III < or > IV

The general trend in organic C based on mean contents is:

Colo Bog:

0-15cm: I < II < III > IV
15-30cm: I < II > III < IV
30-45cm: I < II > III < IV
0-45cm: I < II > III < IV

Harrier's Marsh:

0-15cm: I < II < III < IV
15-30cm: I < II < III < IV
30-45cm: I < II < III < IV
0-45cm: I < II < III < IV

Gordon's Marsh:

0-15cm: I < II < III < IV

15-30cm: I < II < III > IV
30-45cm: I < II = III > IV
0-45cm: I < II < III > IV

Overall:

0-15cm: I < II < III < or > IV
15-30cm: I < II < III < or > IV
30-45cm: I < II ≤ or ≥ III < or > IV
0-45cm: I < II < or > III < or > IV

Overall, group I soils had lower total and organic C contents than group II soils for each depth interval. Group II soils had equal to or lower total C contents than group III soils for each depth interval. No general trends in total and organic C contents were observed between group III and group IV soils for each depth interval. No general trends in organic C contents were observed between group II and III soils from 15-30 and 30-45cm.

The range in total C among the three depth intervals was 831-1667 g m^2 in group I soils, 755-2224 g m^2 in group II soils, 808-2913 g m^2 in group III soils, and 1131-3138 g m^2 in group IV soils in Harrier's Marsh. Lowest variability occurred from 0-15cm in group I soils and 30-45cm in group II-IV soils in this wetland complex. The range in total C among the three depth intervals was 293-641 g m^2 in group I soils, 2297-2758 g m^2 in group II soils, 1995-3812 g m^2 in group III soils, and 4784-8712 g m^2 in group IV soils in Gordon's Marsh. Group I soils exhibited very little variability in total C, whereas group II-IV soils exhibited high variability in total C in Gordon's Marsh.

The range in total C among the three depth intervals was 464-1001 g m^2 in group I soils, 836-1416 g m^2 in group II soils, 737-936 g m^2 in group III soils, and 1534-2617 g m^2 in group IV soils in Colo Bog. Group IV soils had highest variability in total C, whereas total C contents in group I and III soils varied slightly in Colo Bog. Overall, upland prairie soils on summits varied slightly in total C for each depth interval whereas wetland soils on toeslopes (pond depressions) varied greatly in total C.

The range in organic C among the three depth intervals was 780-983 g m^2 in group I soils, 358-1392 g m^2 in group II soils, 910-3079 g m^2 in group III soils, and 1237-2866 g m^2 in group IV soils in Harrier's Marsh. Highest variability in group III and IV soils occurred from 0-15 and 15-30cm in Harrier's Marsh. The range in organic C among the three depth intervals was 293-641 g m^2 in group I soils, 2297-2758 g m^2 in group II soils, 2649-4275 g m^2 in group III soils, and 5286-9239 g m^2 in group IV soils in Gordon's Marsh. The range in organic C among the three depth intervals was 434-701 g m^2 in group I soils, 836-1416 g m^2 in group II soils, 245-989 g m^2 in group III soils, and 804-4257 g m^2 in group IV soils in Colo Bog. Highest variability occurred from 0-15 and 15-30cm in group IV soils in this wetland complex.

Summary

Mollic epipedons in three wetland complexes on the Des Moines Lobe were examined to elucidate the sources of systematic variability among vegetative zones, to determine the variability in soil properties among vegetative zones, hillslopes, and sites, and to measure the carbon status on the restored prairie-wetland hillslopes. Sources of soil systematic variability of interest were site, transect, slope position, and soil depth. Four groups were assigned in each hillslope to describe vegetative zone-slope position interactions. These groups were Group I: upland prairie on summits with moderately well drained soils; Group II: upland prairies on backslopes with poorly drained soils; Group III: wet prairies to sedge wetland zones on footslopes with poorly drained calcareous soils; Group IV: closed pond wetlands on toeslopes with very poorly drained soils. Soil depth explained most of the systematic variability in available K, available P, total C, and organic C in upland prairies and wetland ecosystems. Slope position explained most of the variability in sand and fine silt in both ecosystems. Sources of variability differed among upland prairie and wetland ecosystems for coarse silt, clay, bulk density, extractable Ca and Mg, CEC, pH, extractable Mn, and extractable Fe. When considering each soil group independently, sources of variability differed in soil physical and chemical properties. In general, transect and soil depth accounted for most of the variability in each group.

In general, soils on summits and backslope formed in glacial till and soils on footslopes and toeslopes formed in hillslope sediments. The heterogeneity of the parent material, the degree of past disturbance, and current nutrient cycling accounts for the variability of soil physical and chemical properties in the mollic epipedons on the restored hillslopes. The upper 45cm of the mollic epipedons in group I and II soils typically have loam to clay loam textures. Particle size distribution varied from clay loam, silt loam, and silty clay loam, reflecting the finer size particles in the hillslope sediments. Variability in particle size distribution differed within each hillslope in each wetland complex and among each wetland complex. Upland prairie soils are leached since recharge is the dominant hydrologic process, which explains for the lower pH and soil fertility in group I soils. Group III and IV soils occur on areas on the landscape collecting sediment and improving moisture conditions. These soils have higher CEC, extractable bases, and pH. Group III soils in all wetland complexes occur on the rim of the closed pond depressions and are more calcareous than any other soil group. Near-surface hydrology and vegetation increases evapotranspiration of water in the soil than downward movement resulting in a reversal of leaching where dissolved solids, especially extractable Ca, are transferred and concentrated at the edge. Group III and IV soils had highest amount of total and organic C as would be expected with increased moisture conditions, enhanced anaerobiosis, and the high vegetative biomass production. The total and organic C amounts can be used as reference points for future monitoring influence of restoration practices on C balance. Total and organic C varied considerably for each soil group in each hillslope, among each hillslope in each wetland complex, and among each wetland complex. Spatial relationships and variability attributable to site, transect, vegetation, slope position, and soil depth should be considered when assessing restored prairie-wetland hillslopes.

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CHAPTER 4: SOIL LANDSCAPE RELATIONSHIPS IN RESTORED PRAIRIE-WETLAND HILLSLOPES IN CENTRAL IOWA: MICROBIAL BIOMASS AND ORGANIC CARBON.

A paper to be submitted to the Soil Science Society of America Journal

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Restoration of cultivated hillslopes in Iowa to prairie or wetland vegetation enhances soil quality as shown by soil quality indicators, especially microbial biomass and organic carbon (C). Little information exists understanding spatial relationships of microbial biomass and organic C along restored prairie-wetland hillslopes. A nested sampling design was established within two restored complexes on the Des Moines Lobe to assess the spatial variability of microbial biomass and organic C. Soils were sampled at three soil depths (0-15, 15-30, 30-45cm) on 3 transect elements (upland prairie-summits, upland prairie-backslopes, and sedge wetland-footslopes) in two hillslopes per wetland complex. Soils varied in particle size distribution, organic C, bulk density, and fertility. Highest organic soil C contents and variability was in the sedge wetlands. Highest microbial biomass C was in the upland prairie-backslopes for each depth interval. Greatest variability in soil microbial biomass was in the upland prairie-backslopes. Sedge wetland soils contained the lowest percentage of microbial biomass C, suggesting presence of older and more stable organic fractions. Vegetative zone accounted for 52% of the total systematic variability in organic C, whereas soil depth accounted for 74% of the total systematic variability in microbial biomass C. Sand and clay contents or both were significantly correlated with microbial biomass and organic C in sedge wetland soils. Restoration, using microbial biomass and organic C as indicators, is positively influencing soil quality in these restored prairie-wetland complexes.

Introduction

Soil microbial activity is crucial in nutrient transformations as well as the functioning and structure of ecosystems (Martens, 1995). Soil microbial biomass consists of a small fraction of the organic C yet microbial activities are significant in regulating soil C and N pools. Numerous factors can contribute to the variability in microbial activity in restored ecosystems, such as organic matter quality and quantity, hydrology of the landscape, plant community and production, extent of disturbance, the nature of the parent material, and soil characteristics (Groffman et al., 1996). The nature of the parent material can also influence ecosystem, spatial variability, and soil microbial activities. Groffman and Tiedje (1989) reported wetlands developed on nutrient-poor parent materials supported vegetation with low nutrient status and low levels of microbial activity.

Numerous cultivated hillslopes in Iowa are currently being used for prairie-wetland restoration with upper slopes under prairie vegetation and lower slopes under wetland ecosystems. A common practice of restoration is removal or blockage of drainage tiles to re-establish the natural hydrology, which influences saturation conditions resulting in increased release of dissolved organic C and decreased mobilization of inorganic nutrients and C as CO_2 (Freeman et al., 1997). Considering prairie and wetland ecosystems are an integrated product of internal and external environmental factors, variations in microbial activities can exist within the hillslope, among the ecosystems, and between managed sites. Knowing and understanding the variability between ecosystems and among hillslopes would be useful in functional evaluation in nutrient cycling, C sequestration, soil quality, and ecosystem management functioning. Groffman et al. (1996) studied the variability in microbial biomass within four different wetland types (fens, red maple swamp, clay meadow, and woodland pool). Clay meadow wetlands contained lower amounts of organic matter and microbial biomass. They also reported organic matter and N content were strong regulators of microbial biomass in fens. Hydrology and organic matter quality controlled the variation in microbial biomass in red maple swamps and woodland pools. Dilly et al. (1997) reported microbial biomass content decreased in the order wet grassland > dry grassland > crop rotation > maize monoculture.

This study was conducted to measure the variability of microbial biomass C along restored prairie-wetland hillslopes in the Des Moines Lobe region, IA. Hillslopes consist of numerous Mollisols varying by differences in parent material, topographic position, and drainage or hydrology (Khan and Fenton, 1994). Other systematic spatial components in these hillslopes are differences in elevation, slope length, erosional or depositional processes, vegetation, and past disturbances. Our objective was i.) to partition the source of microbial biomass variability in restored wetland complexes and estimate the relative contribution of each and ii.) to describe the relationship between microbial biomass C with organic C by vegetative zones.

Materials and Methods

<u>Study Sites and Field Methods</u>

Gordon's and Harrier's Marsh are two wetland complexes currently managed by the Department of Natural Resources for wildlife habitat and hunting. They are greater than 100 ha in size and have been under restoration 8 to 13 years when the study began (2000). General landscapes consist of upper slopes under prairie vegetation and lower slopes under wetland vegetation. The wetland complexes are located on the Des Moines Lobe Region (Figure 1). This region represents the last glacial advance of Late Wisconsinan and contains young broad, gently rolling, and low-relief landscapes with poorly integrated drainage systems. General stratigraphy of glacial till landscapes consists of three strata of surficial sediment over the glacial till. The uppermost two strata represent Late Holocene (4300 YBP) slope alluvium deposited by runoff toward foot and toeslopes from adjacent hillslopes (Steinwand and Fenton, 1995). The third lower strata represent early Holocene slope alluvium derived from the erosion of coarse-textured supraglacial sediments from adjacent hillslopes. Hydrology is characterized as recharge on topographic highs, lateral groundwater flow on sideslopes, and discharge in swales.

Two hillslopes with closed depressions were selected within each wetland complex. Vegetative zones on the hillslopes were delineated based on the dominance of species (>50%). Two vegetative zones (prairie and wetland) and three slope positions (summits, backslopes, and sedge wetland zones) were selected for sampling (Tables 1 and 2). Figure 2 illustrates general slope profile along a till landscape. Three sampling sites were then assigned for each hillslope: prairie-summits, prairie-backslopes, and sedge wetland-footslopes. Soils were sampled at three depth intervals (0-15, 15-30, 30-45 cm) in each vegetative-slope area.

Laboratory Analysis

Particle size distribution was determined by the pipette method (Walter et al. 1978). Soil pH was determined in a 1:1 soil:water mixture. Organic C was measured by dry combustion using a LECO CHN analyzer. Cation exchange capacity was determined by the sum of cations. Bulk density was determined by the clod method. Phosphorus was determined by the Mehlich-3 extraction (Soil Survey Staff, 1996). Microbial biomass C was determined by fumigation-extraction method (Vance et al., 1987) and analyzed with a DOC analyzer.

Statistical Methods

The nested design was used to estimate the percentage variability explained by each landscape component (SAS Institute, 1985). The ideal statistical model used to explain the value for an individual variable (Y_{ijk}) is:

$$Y_{ikj} = \mu + C_i + T_{ij} + V_{ijk} + D_{ijkl} + R_{ijklm}$$

where μ equals population means; C_i the wetland complex effects; T_{ij} the transect effects; V_{ijk} the vegetative zone-slope effects; D_{ijkl} the depth interval effects; and R_{ijklm} the random error effects. Pearsons correlation analysis was used to determine correlation coefficients between microbial biomass C and organic C with selected soil properties at each given vegetative zone. Simple linear regression was used to describe relationship between microbial biomass C and organic C. Significance was tested at the 0.05 level.

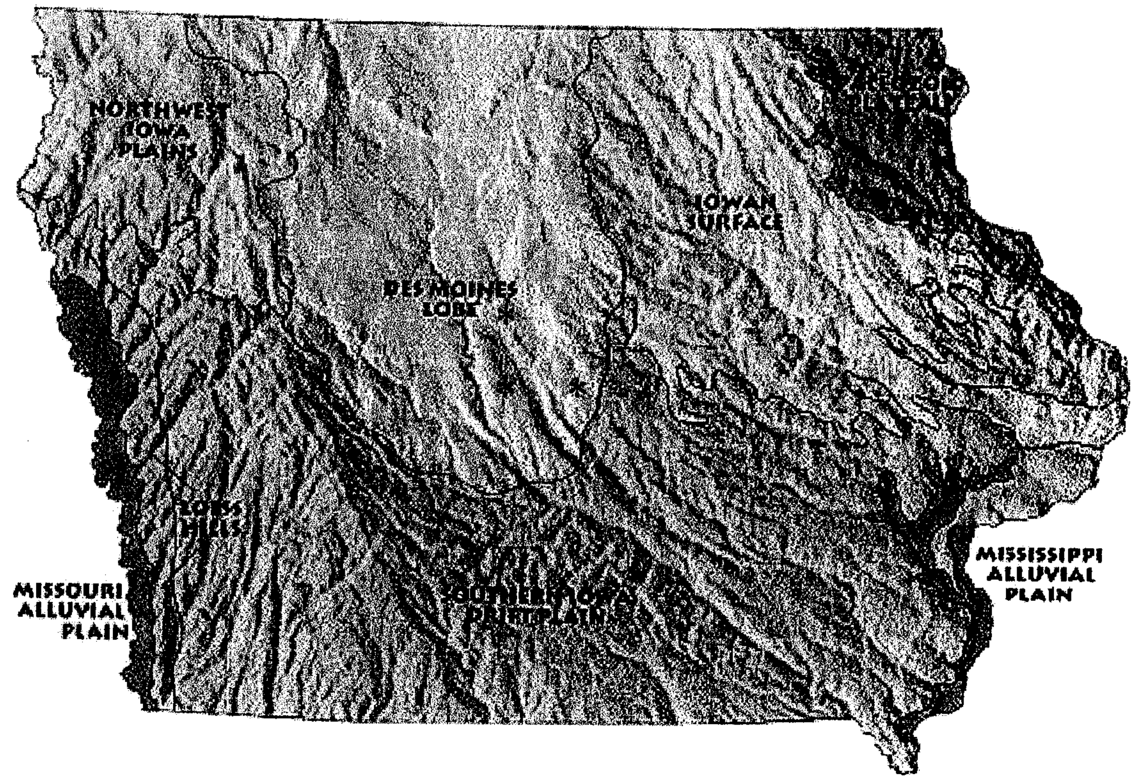


Figure 1. Location of study sites on the Des Moines Lobe.

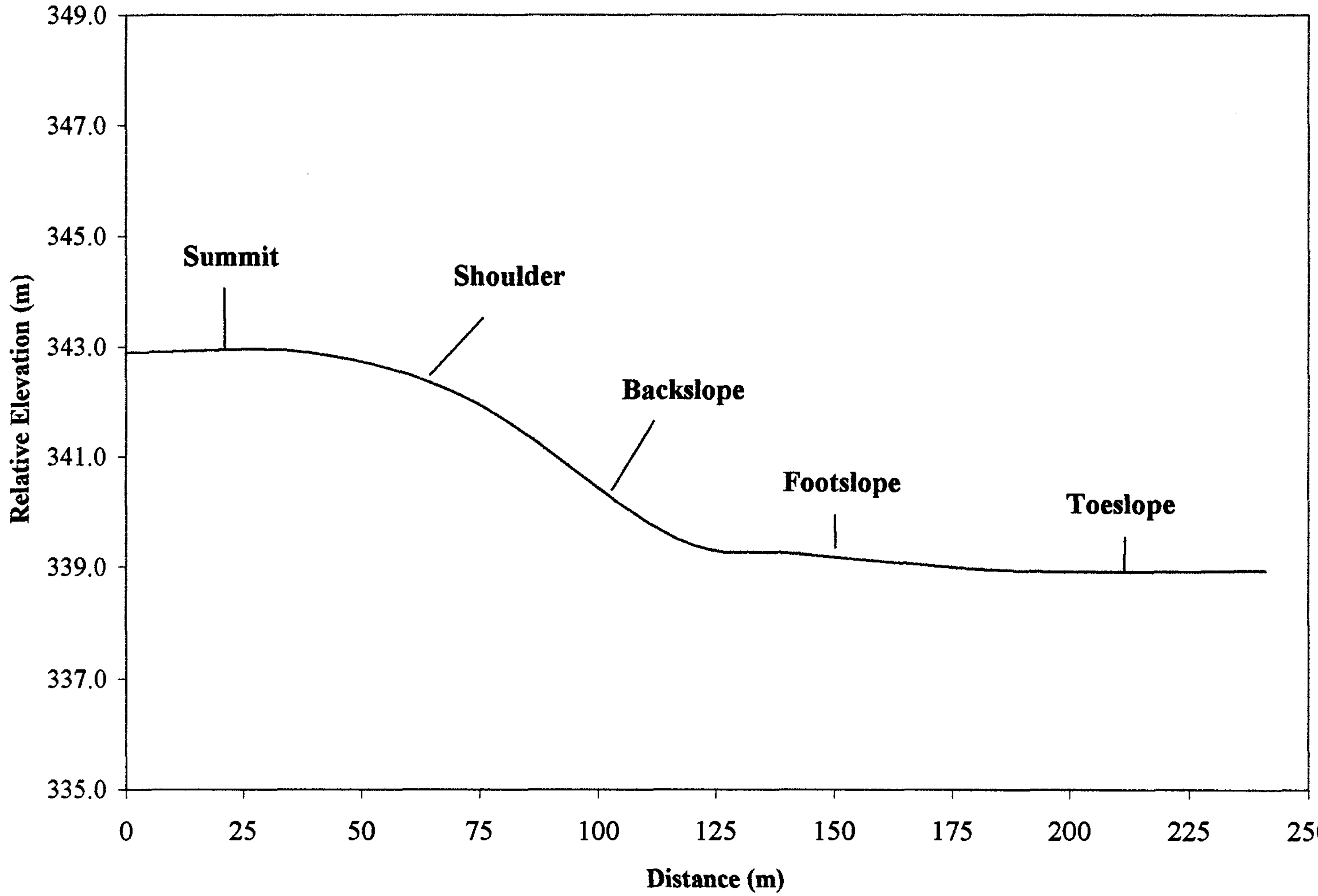


Figure 2. Typical slope profile in a till hillslope.

Table 1. Common species and aboveground biomass production along each hillslope in Gordon's Marsh.

Vegetative Zone	Slope Position	Common Species	Aboveground Biomass Production kg/ha
		Transect 1	
Upland Prairie	Summit	*Andropogon and Panicum* species.	22480
Upland Prairie	Backslope	*Andropogon and Panicum* species.	20810
Sedge Wetland Zone	Footslope	*Duluchium arundinaceum* (3-way Sedge)	21110
		Transect 2	
Upland Prairie	Summit	*Andropogon and Panicum* species.	13610
Upland Prairie	Backslope	*Andropogon and Panicum* species.	12020
Sedge Wetland Zone	Footslope	*Carex typhina* (Cattail Sedge)	18900

Table 2. Common species and aboveground biomass production along each hillslope in Harrier's Marsh.

Vegetative Zone	Slope Position	Common Species	Aboveground Biomass Production kg/ha
		Transect 1	
Upland Prairie	Summit	*Andropogon and Panicum* species.	11450
Upland Prairie	Backslope	*Andropogon and Panicum* species.	15260
Sedge Wetland Zone	Footslope	*Carex typhina* (Cattail Sedge)	18520
		Transect 2	
Upland Prairie	Summit	*Andropogon and Panicum* species.	16500
Upland Prairie	Backslope	*Andropogon and Panicum* species.	15380
Sedge Wetland Zone	Footslope	*Duluchium arundinaceum* (3-way Sedge)	14710

Results and Discussion

Soil Attributes

Each hillslope transect varied in soil series (Table 3). Soils on the upland prairie-summits were classified as Clarion and Nicollet soils. Soil classification for these soils was fine-loamy, mixed, superactive, mesic Typic or Aquic Hapludolls. The soils in these areas are moderately well to somewhat poorly drained. The soil series on the upland prairie-backslopes were Webster and Delft. Soil classification was fine-loamy/silty, mixed, superactive, mesic Typic or Cumulic Endoaquolls. The soils in these areas are poorly drained. Delft soils have cumulic mollic epipedons derived from erosional/depositional processes due to past disturbances rather from anaerobiosis. The soil series in the sedge wetland-footslopes were Canisteo and Delft. Canisteo soils are calcareous throughout the sola and are poorly drained. The Delft soils in the sedge zone in transect 1 of Gordon's Marsh were calcareous and have a fine-silty family designation, reflecting organo-silt accumulation from past erosional/depositional processes.

Soils varied in particle size distribution, pH, organic C, CEC, available P, and bulk density (Tables 4-5). Soils in the upper 45 cm in upland prairie-summits had loam to clay loam textures with moderately/slightly acid soil reaction. Sand contents ranged from 31.8-36.1%, silt contents from 34.0-43.1%, and clay contents from 21.6-32.9%. Soil pH ranged from 5.2 to 6.7. The upper 15 cm were enriched with available P in the summits, ranging from 15 to 45 mg/kg. Bulk density ranged from 1.09-1.31 g cm^3. The higher bulk densities occurred from 15-30 cm, reflecting compaction from trafficking by machinery utilized by the wetland managers as part of their management practice or by past agricultural practices. Soils in the upper 45 cm on upland prairie-backslopes had loam to clay loam textures with slightly acid reaction. Sand contents ranged from 23.8-39.1%, silt contents from 33.5-50.6%, and clay contents from 23.6-30.1%. Soil pH ranged from 5.7-6.8. Available P contents from 0-15cm ranged from 8-36 mg/kg in the backslopes. Mechlich-P decreased drastically with depth in the summits and backslopes. Bulk density ranged from 1.05-1.32 g/cm^3 in the backslopes.

Table 3. Soil series and classification along the restored wetland complexes.

Vegetation	Slope Position	Soil Series	Drainage	Classification
		Harrier's Marsh-Transect 1		
Prairie	Summit	Clarion	Moderately Well	Fine-loamy, mixed, superactive, mesic Typic Hapludoll
Prairie	Backslopes	Webster	Poor	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll
Sedge Wetland Zone	Footslopes	Canisteo	Poor	Fine-loamy, mixed, superactive, calcareous mesic Typic Endoaquoll
		Harrier's Marsh-Transect 2		
Prairie	Summit	Clarion	Moderately Well	Fine-loamy, mixed, superactive, mesic Typic Hapludoll
Prairie	Backslopes	Delft	Poor	Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll
Sedge Wetland Zone	Footslopes	Canisteo	Poor	Fine-loamy, mixed, superactive, calcareous mesic Typic Endoaquoll
		Gordon's Marsh-Transect 1		
Prairie	Summit	Nicollet	Somewhat Poor	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll
Prairie	Backslopes	Delft	Poor	Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll
Sedge Wetland Zone	Footslopes	Delft	Poor	Fine-silty, mixed, superactive, calcareous, mesic Cumulic Endoaquoll
		Gordon's Marsh-Transect 2		
Prairie	Summit	Nicollet	Somewhat Poor	Fine-loamy, mixed, superactive, mesic Aquic Hapludoll
Prairie	Backslopes	Webster	Poor	Fine-loamy, mixed, superactive, mesic Typic Endoaquoll
Sedge Wetland Zone	Footslopes	Canisteo	Poor	Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Table 4. Selected soil properties along the restored hillslopes in Harrier's Marsh.

Vegetative Zone	Slope Position	Depth cm	Sand %	Silt %	Clay %	pH	CEC cmol kg^{-1}	Mehlich-P mg kg^{-1}soil	NO3 mg kg^{-1}soil	Bulk Density g cm^{-3}	TC %	TN %
						Transect 1						
Upland Prairie	Summits	0-15	35.0	40.1	24.9	6.7	17.8	44	<1	1.12	2.5	0.32
		15-30	30.1	42.5	27.4	6.1	18.6	6	<1	1.24	2.2	0.29
		30-45	30.6	41.6	27.8	6.4	17.3	7	<1	1.11	2.0	0.29
Upland Prairie	Backslopes	0-15	38.2	38.2	23.6	6.6	18.8	33	<1	1.32	2.7	0.33
		15-30	37.8	38.0	24.2	6.3	20.5	5	<1	1.31	2.1	0.27
		30-45	35.8	38.7	25.5	6.5	22.6	4	<1	1.24	1.8	0.25
Wetland Zone	Footslopes	0-15	22.6	47.7	29.7	7.1	28.9	49	2	1.08	3.7	0.44
		15-30	24.4	46.6	29.0	7.6	34.7	24	3	1.32	3.3	0.38
		30-45	26.8	44.0	29.2	7.7	32.4	13	1	1.40	2.7	0.37
						Transect 2						
Upland Prairie	Summits	0-15	35.5	42.9	21.6	5.3	10.7	15	<1	1.09	1.9	0.32
		15-30	34.6	40.9	24.6	5.2	10.9	7	<1	1.31	1.6	0.27
		30-45	34.3	39.4	26.3	5.7	13.4	6	<1	1.13	1.7	0.27
Upland Prairie	Backslopes	0-15	33.7	42.3	24.0	5.7	15.4	36	<1	1.27	2.7	0.34
		15-30	33.5	42.0	24.5	5.9	17.9	9	<1	1.10	2.4	0.30
		30-45	29.5	43.6	26.9	6.2	18.2	5	<1	1.05	2.4	0.32
Wetland Zone	Footslopes	0-15	28.7	45.2	26.2	7.7	36.4	14	6	1.21	3.8	0.44
		15-30	23.7	48.2	28.1	7.8	37.1	8	2	1.31	4.0	0.44
		30-45	29.4	43.3	27.3	7.8	30.3	4	<1	1.37	2.2	0.31

Table 5. Selected soil properties along the restored hillslopes in Gordon's Marsh.

Vegetative Zone	Slope Position	Depth cm	Sand %	Silt %	Clay %	pH	CEC cmol kg^{-1}	Mehlich-P mg kg$^{-1 soil}$	NO3 mg kg$^{-1 soil}$	Bulk Density g cm^{-3}	TC %	TN %
						Transect 1						
Upland Prairie	Summits	0-15	31.8	43.1	25.1	5.6	17.7	41	<1	1.15	2.7	0.28
		15-30	32.6	34.5	32.9	5.8	19.3	4	<1	1.15	2.3	0.26
		30-45	34.8	34.0	31.2	5.8	19.2	4	<1	1.13	1.9	0.24
Upland Prairie	Backslopes	0-15	28.1	48.2	23.7	6.1	25.8	30	3	1.24	3.3	0.32
		15-30	25.4	50.3	24.3	6.3	30.4	9	<1	1.24	3.2	0.33
		30-45	23.8	50.6	25.6	6.4	28.7	6	<1	1.23	2.7	0.26
Wetland Zone	Footslopes	0-15	17.7	51.7	30.6	7.3	40.3	27	4	1.06	7.0	0.64
		15-30	10.1	57.3	32.6	7.4	41.6	30	5	1.09	7.4	0.69
		30-45	15.1	56.1	28.8	7.4	28.4	6	2	1.14	2.6	0.36
						Transect 2						
Upland Prairie	Summits	0-15	36.1	37.5	26.4	5.6	17.2	18	<1	1.23	2.4	0.28
		15-30	35.3	37.8	26.9	5.6	16.8	12	<1	1.29	2.2	0.26
		30-45	32.6	37.0	30.4	5.8	17.1	5	<1	1.16	1.8	0.22
Upland Prairie	Backslopes	0-15	39.1	34.4	26.5	6.0	18.3	8	<1	1.16	2.4	0.28
		15-30	37.0	34.0	29.0	6.1	19.5	3	<1	1.19	2.2	0.27
		30-45	36.4	33.5	30.1	6.8	23.7	3	<1	1.19	1.5	0.21
Wetland Zone	Footslopes	0-15	28.3	44.8	26.9	7.7	33.9	25	<1	1.22	4.0	0.42
		15-30	26.7	46.6	26.7	7.9	36.2	16	<1	1.22	3.8	0.42
		30-45	25.1	45.7	29.2	7.9	30.9	6	<1	1.31	1.7	0.23

Soils from 0-45cm in the sedge wetland had loam to silty clay loam textures with neutral to slightly alkaline soil reaction. Sand contents ranged from 10.1-29.4%, silt contents from 43.3-57.3%, and clay contents from 26.2-32.6%. Soil pH ranged from 7.1-7.9. Mehlich P was high from 0-30cm and decreased drastically from 30-45cm. Bulk densities ranged from 1.06-1.40 g cm^3.

<u>Organic and Microbial Biomass C</u>

To better describe its variability and differences along the landscape, organic C was converted to a mass basis. Mean organic C (n=4) increased significantly from summits to footslopes (Figure 3). Mean organic C decreased slightly with depth in the upland prairie-summits and backslopes, but decreased drastically at 30-45cm in the footslopes. The root systems in the sedge zones were not fibrous but thick tuberous to rhizomous systems that dominate the upper 30 cm. The sedge zone also produced high amounts of aboveground biomass. Therefore, organic C would accumulate significantly at these depths in the sedge zone-footslopes. The majority of the total C in the footslopes was organic as the calcium carbonate equivalents were less than 30 g/kg. The highest variability in organic C occurred in the sedge wetlands (Figure 4). Organic C varied slightly among wetland complexes and hillslope transects in the upland prairie-summits and backslopes. The highest content of organic C occurred in transect 1 of Gordon's Marsh. The soil texture from 0-45 cm in this zone was silty clay loam. The high amounts are due to past sedimentation of stable fine-organo rich particles in conjunction with current accumulation from restoration.

Greatest microbial biomass C occurred from 0-15cm in all vegetative zones (Figure 5). Highest mean microbial biomass C occurred in the upland prairie-backslopes for all depth intervals. Mean microbial biomass C decreased significantly from 0-15cm to 15-45cm in the upland prairie-summits, with greatest decrease in microbial biomass C from 0-15 with 15-30cm. The decrease in mean microbial biomass with depth was more gradual in the upland prairie-backslopes and sedge wetland. Lowest biomass C occurred in the sedge wetland from 0-30 cm but was lowest in the upland prairie-summits from 30-45 cm. Each vegetative zone varied in microbial biomass C for each

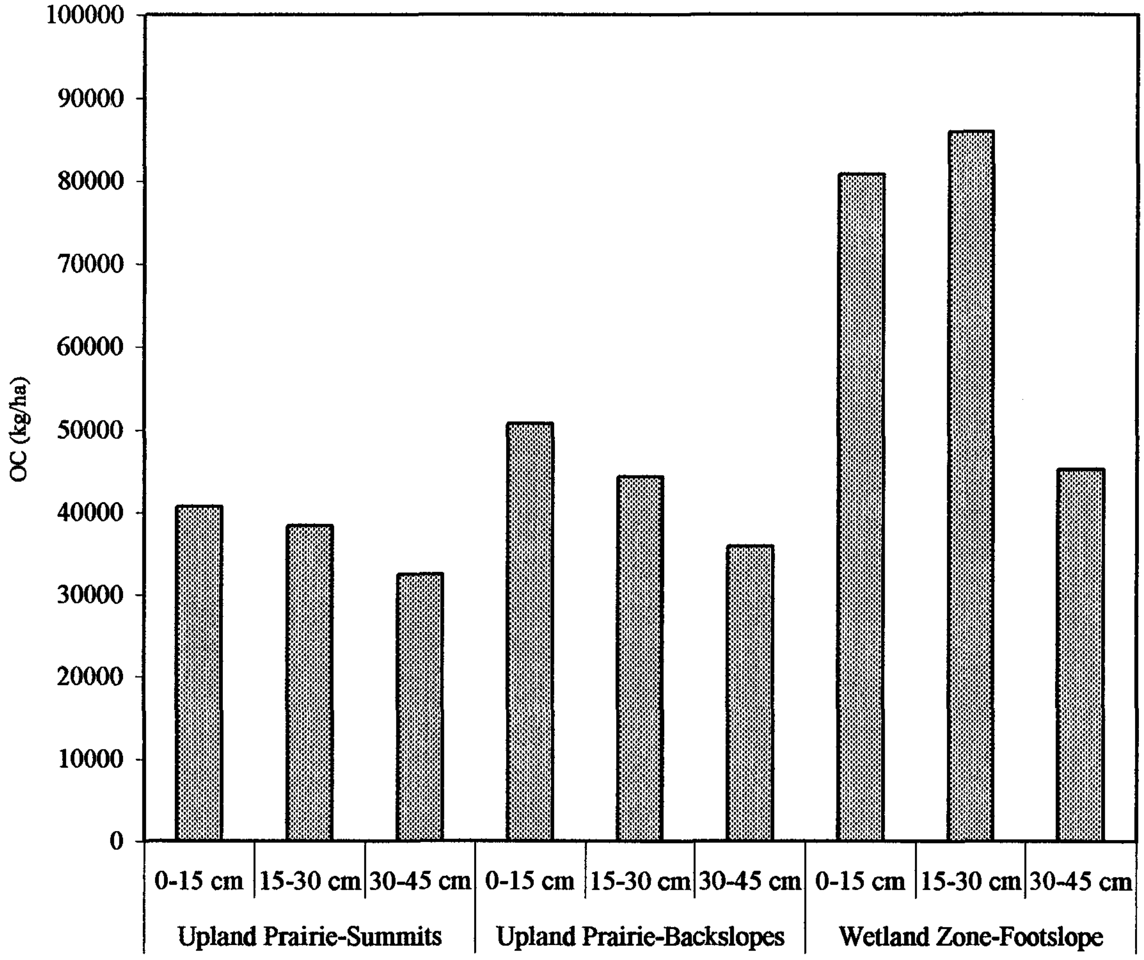


Figure 3. Mean organic C contents on the restored hillslopes.

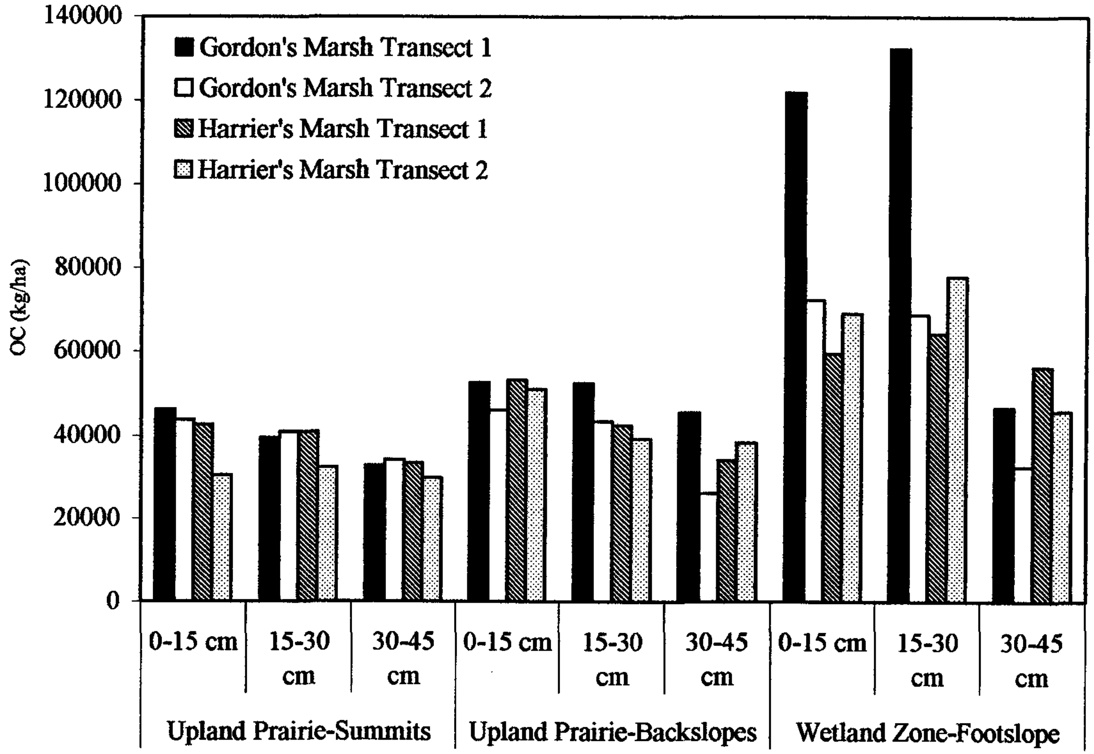


Figure 4. Organic C contents along the restored hillslopes.

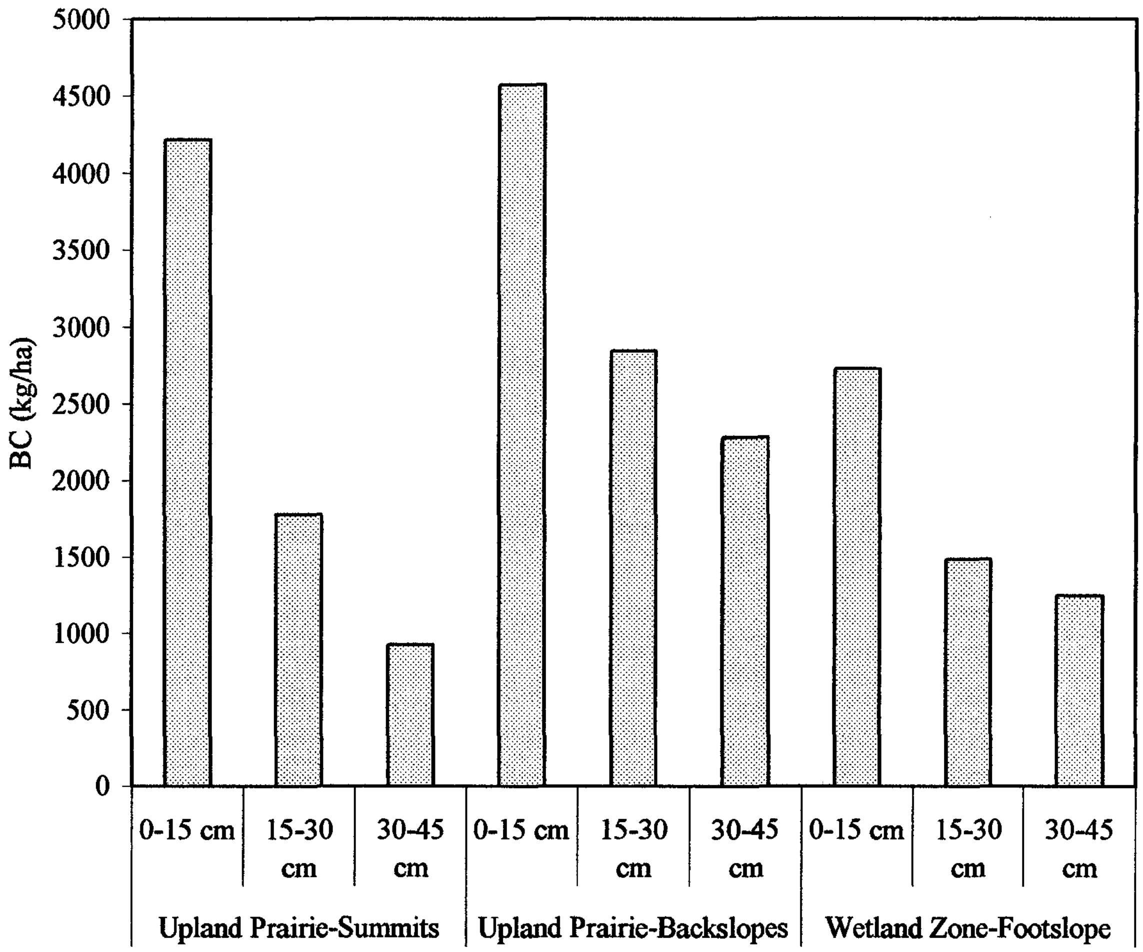


Figure 5. Mean microbial biomass C along the restored hillslopes.

hillslope transect (Figure 6). The range in microbial biomass C in the upland prairie-summits was 2600 kg/ha from 0-15cm, 880 kg/ha from 15-30cm, and 964 kg/ha from 30-45cm. The range in microbial biomass C in the backslopes was 3300 kg/ha from 0-15 cm, 2400 kg/ha from 15-30cm, and 2275 kg/ha from 30-45cm. The range in microbial biomass C in the sedge wetland was 4300 kg/ha from 0-15cm, 2200 kg/ha from 15-30cm, and 1700 kg/ha from 30-45cm. The backslopes contained the greatest variability in microbial biomass C.

Mean microbial biomass C comprised 8-10% of the organic C from 0-15 cm in the upland prairie-summits and backslopes (Figure 7). Mean microbial biomass C comprised 4-6% of the organic C in the upland prairie-summits and backslopes from 15-30cm. Mean biomass C consisted of approximately 2% of the organic C from 30-45cm in the upland prairie-summits, but comprised over 6% of the organic C at this depth interval in the backslopes. In the sedge wetland, mean microbial biomass C comprised 2-3% of the organic C from 0-45cm, reflecting the greater abundance of stable organic matter in these zones and younger organic matter in prairie ecosystems. Each wetland complex site and hillslope also varied in percentage microbial biomass C (Figure 8). The upland prairie-backslopes contained the greatest variability in percentage microbial biomass C. The range in the upland prairie-summits was 4% from 0-15cm and 3% from 15-45cm. The range in the upland prairie-backslopes was 6% from 0-15cm and 3% from 15-45cm. The range in the sedge wetland was 2% from 0-30cm and 3% from 30-45cm.

Table 6 illustrates correlation coefficients between organic C and microbial biomasss C with selected soil properties for each landscape component. Microbial biomass C was positively correlated with sand and silt contents in the upland prairie-summits, but was not statistically significant. Microbial biomass C was negatively correlated with clay content and pH, but was found not statistically significant in the upland prairie-summits. Organic C was poorly correlated with all soil parameters on the summits. On the backslopes, microbial biomass C was negatively correlated with sand and clay content and pH but was positively correlated with silt content. All

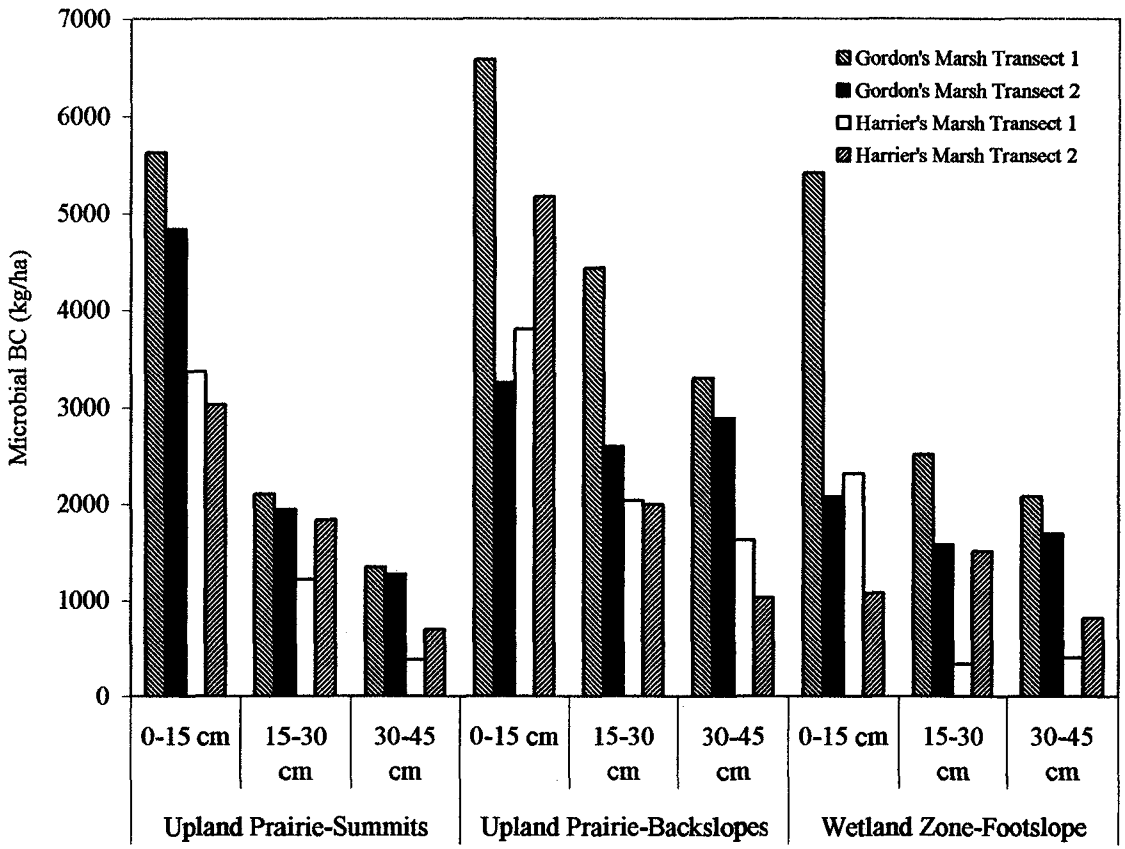


Figure 6. Microbial biomass C production on each restored hillslopes.

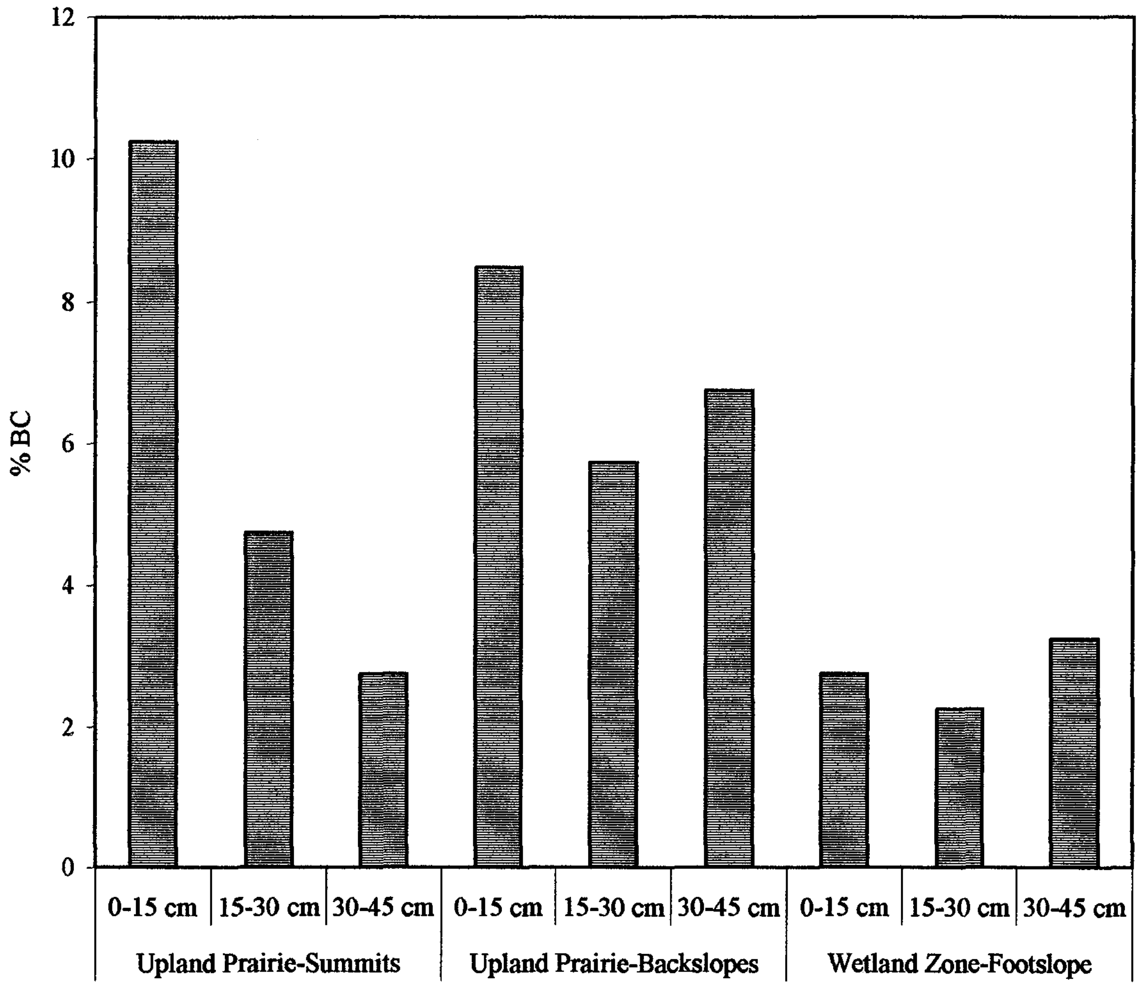


Figure 7. Comparison between mean % BC along the restored hillslopes.

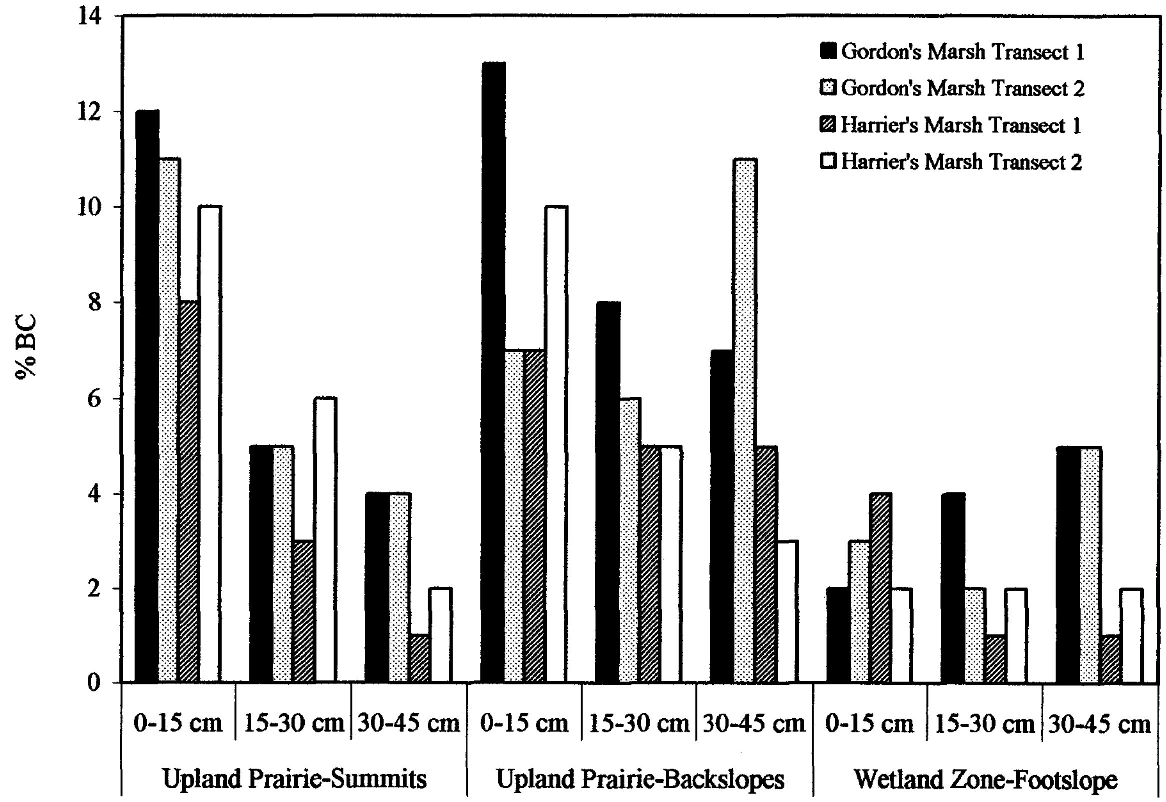


Figure 8. Variability of % microbial biomass carbon on the restored hillslopes.

Table 6. Correlation coefficients between microbial biomass C and organic C with selected soil properties.

Vegetation	Slope Position		Sand	Silt	Clay	pH	Bulk Density	OC
Upland Prairie	Summits	BC	0.30	0.21	-0.40	-0.20	0.01	0.69*
		OC	-0.12	0.06	0.02	0.26	0.19	-
Upland Prairie	Backslopes	BC	-0.31	0.43	-0.46	-0.24	0.47	0.70*
		OC	-0.28	0.49	-0.74*	-0.43	0.44	
Sedge Wetland Zone	Footslopes	BC	-0.80*	-0.80*	0.63*	-0.45	-0.69*	0.60*
		OC	-0.61*	0.57*	0.56*	-0.41	-0.60*	

* significant at 0.05 level.

correlation coefficients were not significantly different at the 0.05 level. Organic C followed the same trend on the upland prairie-backslopes. The correlation between clay content and organic C was significant at the 0.05 level. Microbial biomass C was negatively and significantly correlated with sand and silt contents and bulk densities, but was negatively and not significantly correlated with soil pH in the sedge wetlands. Microbial biomass C was significantly and positively correlated with clay content in these zones. Organic C was positively correlated with silt and clay contents but was negatively correlated with sand contents, bulk densities, and pH. The inherent variability in soils in these landscapes influences the organic C accumulation and microbial biomass C production. The soils in the sedge zones occur as rims along the closed pond depressions and formed from hillslope sediment. These areas also are enriched in carbonates and smectitic-type clays, which influence the moisture status and microbial activities.

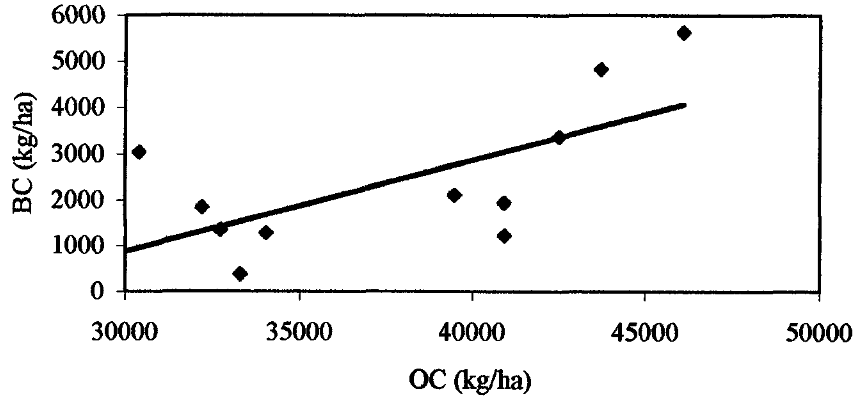
Most of the total systematic variability for microbial biomass C was explained by soil depth (Table 7). Wetland complex and hillslope explained for 20 and 6% of the total systematic variability in microbial biomass C. Vegetative zone and soil depth accounted for 52% and 48% of the total systematic variability in organic C, respectively. Stolt et al. (2001) reported site and soil depth explained 57 and 30% of the total variability in organic C in their study of five palustrine wetlands in Virginia. Significant linear relationships were computed between organic and microbial C for each vegetative zone (Figure 9, Table 8). Slopes were statistically significant for the model in each landscape zone, but the intercept was not statistically significant on all vegetative zones.

Table 7. Partitioning of systematic variability for microbial biomass and organic C in the restored wetland complexes.

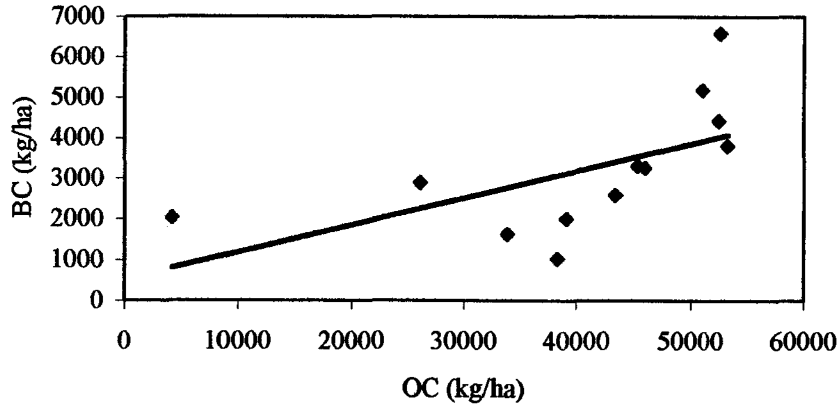
Variable	Research Site	Hillslope	Vegetative Zone	Soil Depth
		%		
Biomass C	20	7	0	73
Organic C	0	0	52	48

Table 8. Empirical linear relationships between microbial biomass C (Y) and organic C (X) in the restored prairie-wetland hillslopes.

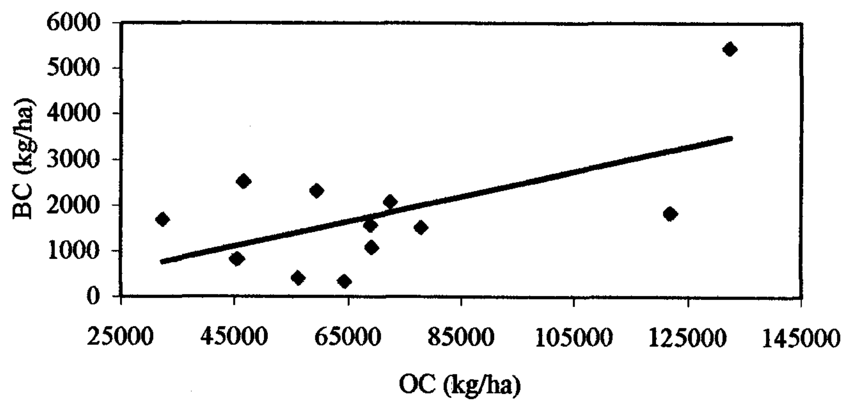
Vegetation	Slope	Equation kg/ha	R^2	P	P-value Intercept	P-value Slope
Prairie	Summits	Y = 0.20X - 5086	0.48	0.012	0.07	0.012
Prairie	Backslopes	Y = 0.07X + 526	0.36	0.040	0.67	0.040
Sedge Wetland Zone	Footslopes	Y = 0.03X – 139	0.36	0.038	0.88	0.039



a.) upland prairie-summits



b.) upland prairie-backslopes



c.) Sedge Wetland Zone-Footslopes

Figure 9. Relationship between microbial biomass C with organic C among vegetative zones.

Summary

This study was conducted to measure the variability of microbial biomass C along restored prairie-wetland hillslopes and to assess the relationship with organic C. Two wetland complexes were selected on the Des Moines Lobe for the study. Two hillslope were selected in each wetland complex. Soils were sampled at three vegetative zone-slope positions and three depth intervals. The soil properties varied in particle size distribution, bulk density and general fertility for each hillslope. All soils in each vegetative zone have large amounts of organic C with the most found in the sedge wetland on footslopes and the least on the upland prairie-summits. Organic C contents were intermediate in the upland prairie-backslopes. Greatest variability in soil organic C accretion occurred in the sedge wetland zones. Soils on upland prairie-backslopes produced the highest microbial biomass C for each depth interval. Highest microbial biomass C was from 0-15cm in all vegetative-slope areas. Highest variability in microbial biomass C occurred on the upland prairie-backslopes. Soils in the sedge wetlands have the lowest percentage microbial biomass C, suggesting presence of more stable organic fractions due to past erosion/deposition in these areas. Vegetative zone accounted for 52% of the total variability in organic C, whereas soil depth accounted for 74% of the total variability in biomass C. Microbial biomass C was significantly related with organic C for each vegetative-slope element. Particle size distribution was significantly correlated with microbial biomass and organic C in the sedge wetland zones. Restoration, using microbial biomass and organic C as indicators, is positively influencing the soil quality in these restored hillslopes.

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CHAPTER 5: GENERAL SUMMARY AND CONCLUSION

A majority of the Iowa landscapes has been drained and put into cultivation, commonly corn and soybean rotations, altering the initial soil state. Increased awareness of the economic and environmental values of prairie and wetland ecosystems has resulted in much of cultivated land being restored to native conditions, especially on the Des Moines Lobe in north-central Iowa. Knowledge of the hydrology, extent and nature of soils, sources of variability, and soil-vegetation interactions are important in proper functioning and maintenance of these restored landscapes. Wetlands serve numerous purposes, such as trapping sediment and water, improving groundwater quality, sinks for carbon, habitats for wildlife, and sorbing contaminants from adjacent sites. Prairies also serve as habitats for wildlife and improve soil quality by providing thick vegetative covers that minimize soil erosion, and enhance aeration and nutrient cycling with their dense fibrous root systems. This project studied soil hydromorphology, hydrology, soil quality, and sources of soil variability of three restored wetland sites on the Des Moines Lobe in Boone, Hamilton, and Story Counties.

Chapter 2 presents the hydrology and soil morphology on restored landscapes. Four groups were developed to describe the variability in soils, vegetation, and slope position on the hillslopes (Figure 1). Group I soils included upland prairie soils on summit and shoulder slopes with moderately well to somewhat poor drainage. Dominant soils included Clarion and Nicollet soils with some taxadjuncts. These soils are classified as fine-loamy, mixed, superactive, mesic Typic or Aquic Hapludolls. Group II soils included upland prairie soils on backslopes with poor drainage. The dominant soils were Webster, Delft, and Canisteo soils with some taxadjuncts present. These soils are classified as fine loamy/silty, mixed, superactive, (calcareous), mesic Typic or Cumulic Endoaquolls. Group III soils included wet prairies or sedge wetlands on footslopes with poor drainage. The dominant soils were Canisteo and Delft soils with some intergrades present. Soils are classified as fine loamy/silty, mixed, superactive, calcareous, mesic Cumulic or Typic Endoaquoll. Group IV soils occurred in pond depressions on toeslopes with poor and very poor drainage. The dominant mineral soils were Okoboji and Glencoe soils. Dominant organic soil was Klossner. The mineral soils were classified as fine/fine silty/fine loamy, mixed/smectitic, mesic Cumulic Vertic Endoaquoll. The organic soils were classified as fine-loamy, mixed, euic, mesic Terric Haplosaprist. Group II to IV soils in prairie-wetland hillslopes are hydric based on positive correlation between soil morphology and hydrology. Group I soils on a ditch-drained hillslope had relict redoximorphic features in the lower sola. Shallowest water table depths occurred during the months of March to May, the onset of the growing season, and deepest water table depths occurred during the months of August to October, near the end of the growing season. Group IV soils were ponded between 3 to 12 months per year. Group III soils were ponded 0-3 months per year.

Recharge is the dominant process on uplands resulting in leached soils. These soils have slightly acid loamy Bw horizons overlying moderately acid black loam mollic epipedons. The Bw horizon had variable moist chromas of 2-4. In Nicollet soils, the Bw horizons underlies moderately acid to alkaline clay loam Bg horizons. Group III soils are slightly alkaline and calcareous throughout the sola. The edges of these depressions receive water from throughflow. These areas dry out sometime during the growing season where water moves upward in the solum by unsaturated flow in response to plant uptake and evapotranspiration. Evaporation of water leaves dissolved materials in the sola. Group III soils had slightly alkaline clay loam mollic epipedons overlying slightly alkaline clay loam Bg horizons. Soil matrices had low chromas, reflective of Fe reduction and the dark mollic epipedon. The upper part of the Bg horizons had, in general, low chroma mottles or redox depletions whereas the lower Bg horizons display mixture of low and high chroma mottles. The vegetation in Group III soils influence the local hydrology by causing a depression in mean water table depth, reflecting the presence of relatively more phreatophytes or hydrophytes that can act like a water pump. Group IV soils had thick black silty clay loam to clay neutral mollic epipedons overlying thin Fe-reduced Bg horizons. These soils had shallowest depth to redoximorphic features, which occurred as low chroma mottles or high/low chroma pore linings in the upper soil horizons.

Soil morphology correlated with hydrology. Class IV soils are on discharge areas as indicated by an upward trend in mean water table depths along the soil surface.

The study in Chapter 3 elucidated and quantified the sources of soil systematic variability in the mollic epipedon along the restored hillslopes and presented the carbon status along the restored hilllslopes. Sources of soil systematic variability of interest were site, hillslope, slope position, and soil depth. Soil depth explained most of the systematic variability in exchangeable K, Mehlich-P, total C, and organic C in upland prairies and wetland ecosystems. Slope position explained most of the variability in sand and fine silt in both ecosystems. Sources of variability differed among upland prairie and wetland ecosystems for coarse silt, clay, bulk density, exchangeable Ca and Mg, CEC, pH, Mn, and Fe. When considering each soil group independently, sources of variability differed in soil physical and chemical properties. In general, hillslope and soil depth accounted for most of the variability in each group.

Mollic epipedon in Group III and IV soils have higher CEC, exchangeable bases, pH, and total and organic C as a result of increased moisture conditions, enhanced anaerobiosis, and the high vegetative biomass production. The total and organic C amounts can be used as reference points for measuring change in C balance with time in restored landscapes. Total and organic C varied considerably for each soil class on each hillslope, among each hillslope in each wetland complex, and among each wetland complex. Spatial relationships and variability attributable to site, hillslope, vegetation, slope position, and soil depth should be considered when assessing restored prairie-wetland hillslopes.

Chapter 4 discussed the variability of microbial biomass C along restored prairie-wetland hillslopes and their relationship with organic C. Soils on upland prairie-backslopes produced the highest microbial biomass C for each depth interval. Highest microbial biomass C was from 0-15cm in all vegetative-slope areas. Highest variability in microbial biomass C occurred on the upland prairie-backslopes. Soils in the sedge wetlands have the lowest percentage microbial biomass C, suggesting presence of more stable organic fractions due to past erosion/deposition in these areas. Vegetative zone accounted for 52% of the total variability in organic C, whereas soil depth accounted for 74% of the total variability in biomass C. Microbial biomass C was significantly related to organic C for each vegetative-slope element. Particle size distribution was significantly correlated with microbial biomass and organic C in the sedge wetland zones. Restoration, using microbial biomass and organic C as indicators, is positively influencing the soil quality on these restored hillslopes. Spatial relationships and variability attributable to site, hillslope, vegetation, slope position, and depth should be considered when assessing soil quality on the restored hillslopes.

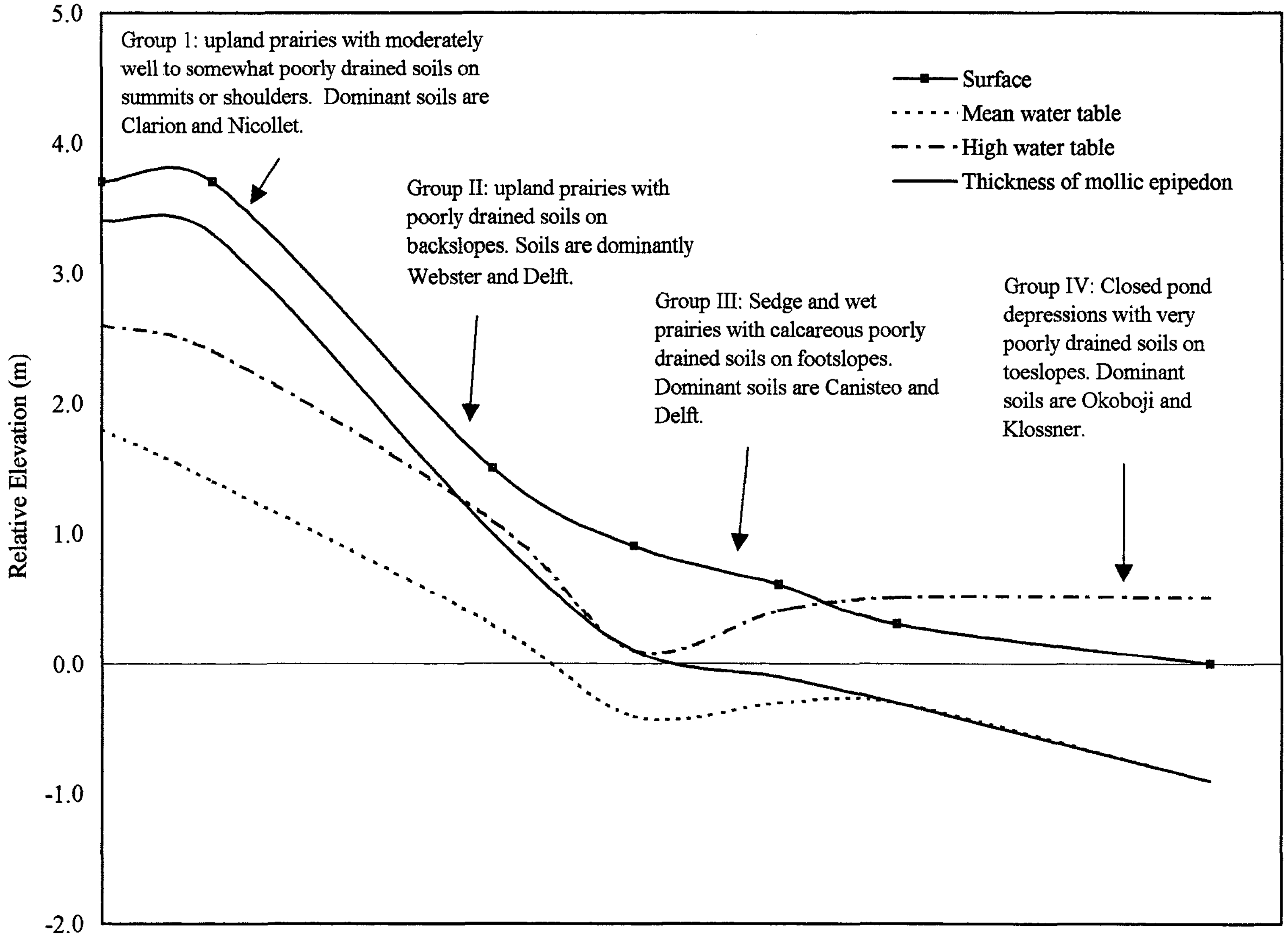

Figure 1. General location of groups on a restored prairie-wetland complex.

APPENDIX A. SOIL DESCRIPTIONS AND CHARACTERIZATION DATA FOR WELLS IN COLO BOG COMPLEX

Soil descriptions for well 1 on transect 1

Clarion loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Typic Hapludoll

Horizon	Soil Description
A1	0 – 18 cm; black (10YR 2/1) loam; weak fine subangular blocky structure; friable; many medium and fine roots; 3-5% fine gravel; strongly acid; abrupt smooth boundary.
A2	18 – 43 cm; very dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; friable; many fine roots; 2-5% fine gravel; slightly acid; clear smooth boundary.
A3	43 – 56 cm; very dark gray (10YR 3/1) silty clay loam; weak fine subangular blocky structure; friable; common fine roots; 2% fine gravel; few very dark grayish brown (10YR 3/2) coating on ped faces; slightly acid; clear smooth boundary.
Bw1	56 – 74 cm; dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) clay loam; weak fine subangular blocky structure; friable; few fine roots; 2% fine gravel; few very dark gray (10YR 3/1) krotovinas; slightly acid; abrupt smooth boundary.
Bw2	74 – 86 cm; dark grayish brown (10YR 4/2) sandy loam; weak fine subangular blocky structure; friable; few fine very dark gray (10YR 3/1) coatings on ped faces; few fine roots; few fine and medium stones; 2% fine gravel; neutral; abrupt smooth boundary.
Bw3	86 – 97 cm; dark grayish brown (10YR 4/2) sandy loam; weak fine subangular blocky structure; friable; few coarse dark brown (7.5YR 3/3) mottles; few fine roots; few fine to coarse stones; 5% fine gravel; slightly acid; abrupt smooth boundary.
Bw4	97 – 102 cm; dark yellowish brown (10YR 4/4), dark grayish brown (10YR 4/2) and grayish brown (2.5Y 5/2) sandy loam; weak fine subangular blocky structure; friable; very few fine dark brown (7.5YR 3/3) mottles; few fine roots; few fine to coarse stones; common fine Mn concretions; neutral; abrupt smooth boundary.
C1	102 – 109 cm; dark yellowish brown (10YR 4/4) and dark grayish brown (10YR 4/2) sandy loam; weak fine subangular blocky structure; friable; few fine roots; few fine and medium stones; 5% fine gravel; common fine Mn concretions; neutral; abrupt smooth boundary.
C2	109 – 135 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few fine roots; few fine and medium stones; common fine olive brown (2.5Y 4/4) mottles; few very fine dark yellowish brown (10YR 4/6) mottles; slightly alkaline; clear smooth boundary.
C3	135 – 188 cm; olive brown (2.5Y 4/4) loam; massive; friable; few fine to coarse grayish brown (2.5Y 5/2) Fe depletions; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; many fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
C4	188 – 226 cm; light olive brown (2.5Y 5/4) sandy loam; massive; friable; few medium and coarse dark grayish brown (2.5Y 5/2) Fe depletions; very few fine dark yellowish brown (10YR 4/6) mottles; many fine to coarse stones; strong reaction to 10% HCl.

Characterization data for well 1 in Colo Bog Complex.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolomite	Ratio	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 18	39.0	18.3	20.5	22.2	2.84	-	-	2.81	-	-	-	5.5
A2	18 – 43	22.5	18.7	30.2	28.6	1.85	-	-	1.85	-	-	-	6.1
A3	43 – 56	17.7	18.0	34.3	30.0	1.18	-	-	1.18	-	-	-	6.4
Bw1	56 – 74	21.5	16.8	32.1	29.7	0.75	-	-	0.75	-	-	-	6.4
Bw2	74 – 86	52.6	12.5	14.4	20.6	0.38	-	-	0.38	-	-	-	6.6
Bw3	86 – 97	70.9	8.8	6.3	14.0	0.37	-	-	0.37	-	-	-	6.3
Bw4	97 – 102	54.6	14.0	14.9	16.5	0.16	-	-	0.16	-	-	-	6.9
C1	102 – 109	73.8	7.8	5.7	12.7	0.28	-	-	0.28	-	-	-	6.8
C2	109 – 135	49.2	13.5	18.3	19.0	0.21	9.2	1.11	0.21	0.5	8.1	0.06	7.4
C3	135 – 188	48.8	14.1	19.2	17.8	3.35	27.9	3.35	-	6.4	19.9	0.32	7.9
C4	188 – 226	53.0	12.1	18.5	16.4	2.31	19.2	2.31	-	4.4	13.7	0.32	8.0

Global Positioning System (GPS) coordinates:

42.01.0996N 93.15.0957W

Soil descriptions for well 2 on transect 1

Nicollet loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 20 cm; black (10YR 2/1) loam; weak fine granular structure; friable; many fine and medium roots; 2% fine gravel; strongly acid; clear smooth boundary.
A2	20 – 43 cm; very dark gray (10YR 3/1) clay loam; moderate fine subangular blocky structure; friable; many fine roots; 2% fine gravel; moderately acid; clear smooth boundary.
A3	43 – 58 cm; very dark gray (10YR 3/1) clay loam; moderate fine subangular blocky structure; friable; common fine roots; 2% fine gravel; few fine very dark grayish brown (2.5Y 3/2) coatings on ped faces; moderately acid; abrupt smooth boundary.
Bg1	58 – 66 cm; dark grayish brown (2.5Y 4/2) clay loam; moderate medium subangular blocky structure; friable; few fine yellowish brown (10YR 5/8) and light olive brown (2.5Y 5/6) mottles; few very dark gray (10YR 3/1) coatings on ped faces; few fine roots; 2-3% fine gravel; few fine stones; moderately acid; clear smooth boundary.
Bg2	66 – 79 cm; dark grayish brown (2.5Y 4/2) sandy loam; moderate medium subangular blocky strucuture; friable; common fine olive brown (2.5Y 4/4) mottles; few dark yellowish brown (10YR 3/6) Fe concretions; few fine Mn concretions; few fine roots; 2% fine gravel; few fine stones; slightly acid; abrupt smooth boundary.
Cg1	79 – 122 cm; dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) loamy sand; single grain; loose; few Mn concretions; few fine and medium stones; neutral; abrupt smooth boundary.
Cg2	122 – 140 cm; grayish brown (2.5Y 5/2) and olive brown (2.5Y 4/4) loamy sand; single grain; loose; few coarse dark yellowish brown (10YR ¾) mottles; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	140 – 183 cm; mixed olive brown (2.5Y 4/4), light olive brown (2.5Y 5/4), light yellowish brown (2.5Y 6/4), and light brownish gray (2.5Y 6/2) sandy loam; massive; friable; few fine yellowish brown (10YR 5/4 & 5/8) mottles; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 2 on transect 1 in Colo Bog Complex.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 20	28.1	20.1	26.6	25.2	2.80	-	-	2.80	-	-	-	5.4
A2	20 – 43	22.6	18.0	30.6	28.7	1.76	-	-	1.76	-	-	-	5.6
A3	43 – 58	22.9	18.3	28.5	30.3	1.01	-	-	1.01	-	-	-	5.6
Bg1	58 – 66	28.5	19.0	24.8	27.7	0.58	-	-	0.58	-	-	-	5.7
Bg2	66 – 79	52.8	16.4	13.8	17.0	0.36	-	-	0.36	-	-	-	6.3
Cg1	79 – 122	80.2	7.6	4.6	7.6	0.13	4.5	0.54	-	0.7	3.5	0.20	7.1
Cg2	122 – 140	79.9	8.8	5.4	5.9	0.26	9.4	1.13	-	0.2	8.5	0.02	7.9
2Cg	140 – 183	60.9	17.5	14.2	7.5	1.40	16.6	1.99	-	1.8	13.7	0.13	8.0

GPS coordinates:

42.01.0933N 93.15.1211W

Soil descriptions for well 3 on Transect 1

Nicollet loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 18 cm; black (10YR 2/1) loam; weak fine subangular blocky structure; friable; 5% fine gravel; many fine and medium roots; strongly acid; clear smooth boundary.
A2	18 – 30 cm; very dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; friable; many fine roots; common medium roots; 5% fine gravel; common very fine very dark grayish brown (10YR 3/2) coatings on ped faces; moderately acid; abrupt smooth boundary.
AB	30 – 46 cm; dark brown (10YR 3/3) clay loam; weak fine subangular blocky structure; friable; many fine roots; few medium roots; 2-5% fine gravel; very dark gray (10YR 3/1) coatings on ped faces; moderately acid; abrupt smooth boundary.
Bw1	46 – 58 cm; brown (10YR 4/3) loam; weak fine subangular blocky structure; friable; many fine roots; few fine and medium stones; 2-5% fine gravel; very dark gray (10YR 3/1) coatings on ped faces; neutral; clear smooth boundary.
Bw2	58 – 71 cm; olive brown (2.5Y 4/4) loam; weak fine subangular blocky structure; friable; few fine Mn nodules; few fine roots; few fine to coarse stones; 2-5% fine gravel; neutral; gradual smooth boundary.
Bg	71 – 89 cm; grayish brown (2.5Y 5/2) sandy loam/loam; moderate medium subangular blocky structure; friable; common fine olive brown (2.5Y 4/4) mottles; few Mn concretions; few fine dark yellowish brown (10YR 4/6) mottles; few fine roots; 2-5% fine gravel; few fine to coarse stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg1	89 – 102 cm; light brownish gray (2.5Y 6/2) loam; massive; friable; few fine light olive brown (2.5Y 5/6) mottles; common fine and medium $CaCO_3$ concretions; few fine dark yellowish brown (10YR 4/6) mottles; 2% fine gravel; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg2	102 – 119 cm; light brownish gray (2.5Y 6/2) and light olive brown (2.5Y 5/4) loam; massive; friable; few fine light olive brown (2.5Y 5/6) mottles; few medium CaCO3 concretions; few fine $CaCO_3$ streaks; few Mn concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg3	119 – 140 cm; light brownish gray (2.5Y 6/2) loam; massive; friable; common few to medium light olive brown (2.5Y 5/4) mottles; few fine yellowish brown (10YR 5/8) and dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine and medium $CaCO_3$ streaks; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
Cg1	140 – 173 cm; light brownish gray (2.5Y 6/2) loam; massive; friable; common fine to medium light olive brown (2.5Y 5/4) mottles; common fine Mn concretions; few fine dark yellowish brown (10YR 4/6) mottles; few strong brown (7.5YR 5/8) Fe concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg2	173 – 226 cm; light brownish gray (2.5Y 5/2) loam; massive; friable; many medium light olive brown (2.5Y 5/4) mottles; many fine Mn concretions; few fine and medium strong brown (7.5YR 5/8) Fe concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 3 on transect 1 in Colo Bog

Horizon	Depth cm	Sand %	Co. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 18	33.6	21.8	19.4	25.2	2.52	-	-	2.52	-	-	-	5.4
A2	18 – 30	23.6	23.2	13.4	39.9	2.08	-	-	2.08	-	-	-	5.6
AB	30 – 46	26.6	22.7	21.5	29.2	1.20	-	-	1.20	-	-	-	5.9
Bw1	46 – 58	38.1	20.4	16.7	24.8	0.63	-	-	0.63	-	-	-	6.6
Bw2	58 – 71	51.6	17.1	12.1	19.1	0.87	3.8	0.45	0.32	0.7	2.9	0.24	7.1
Bg	71 – 89	52.1	15.9	12.8	19.2	1.34	7.4	0.89	0.45	0.8	6.1	0.13	7.6
Ckg1	89 – 102	38.9	17.8	21.9	21.4	2.43	20.3	2.43	-	5.2	13.8	0.38	8.2
Ckg2	102 – 119	33.6	15.3	26.1	25.0	2.84	23.7	2.84	-	9.2	13.4	0.69	8.4
Ckg3	119 – 140	39.7	16.6	22.8	20.9	2.63	21.9	2.63	-	6.3	14.4	0.44	8.3
Cg1	140 – 173	42.4	18.5	20.5	18.7	3.04	25.3	3.04	-	5.3	18.5	0.29	8.3
Cg2	173 – 226	48.3	15.4	18.5	17.8	2.55	21.2	2.55	-	5.2	14.8	0.35	8.3

GPS coordinates:

42.01.0933N 93.15.1445W

Soil descriptions for well 4 on transect 1

Nicollet loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 23 cm; very dark brown (10YR 2/2) loam; weak medium subangular blocky structure; friable; 2% fine gravel; many fine roots; strongly acid; clear smooth boundary.
A2	23 – 48 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; 2% fine gravel; many fine roots; slightly acid; clear smooth boundary.
Bw	48 – 76 cm; dark grayish brown (2.5Y 4/2) clay loam; moderate fine subangular blocky structure; friable; common fine roots; few fine and medium stones; 2% fine gravel; many black (2.5Y 2/1) coatings on ped faces; neutral; abrupt smooth boundary.
Bg1	76 – 94 cm; dark grayish brown (2.5Y 4/2) loam; moderate medium subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; common black (2.5Y 2/1) coatings on ped faces; few fine strong brown (7.5YR 5/8) mottles; common fine roots; few fine and medium stones; neutral; abrupt smooth boundary.
Bg2	94 – 109 cm; dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) loam; moderate medium prismatic structure; friable; common fine roots; few fine and medium stones; 2% fine gravel; common fine light olive brown (2.5Y 5/4) mottles; common very dark gray (2.5Y 3/1) coatings on ped faces; few fine yellowish brown (10YR 5/8) mottles; slightly alkaline; clear smooth boundary.
BCg	109 – 124 cm; dark gray (2.5Y 4/1) and grayish brown (2.5Y 5/2) loam; massive; friable; few fine roots; few fine and medium stones; few fine light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) mottles; few strong brown (7.5YR 4/6) concretions; few fine yellowish brown (10YR 5/8) mottles; few Mn oxides; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg1	124 – 150 cm; grayish brown (2.5Y 5/2) loam; massive; friable; common fine light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) mottles; few fine yellowish brown (10YR 5/8) mottles; few Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	150 – 160 cm; grayish brown (2.5Y 5/2) loam; massive; friable; common fine light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine to coarse stones; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary/
Cg3	160 – 208 cm; light olive brown (2.5Y 5/4) loam; massive; friable; few medium grayish brown (2.5Y 5/2) Fe depletions; few Mn concretions; few fine strong brown (7.5YR 4/6) Fe concretions; few fine dark yellowish brown (10YR 4/6) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 4 on transect 1 in Colo Bog.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolomite	Ratio	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 23	29.1	22.1	23.8	25.0	2.72	-	-	2.72	-	-	-	5.4
A2	23 – 48	22.3	20.3	27.3	30.1	2.27	-	-	2.27	-	-	-	6.1
Bw	48 – 76	31.8	17.4	21.9	29.0	1.12	-	-	1.12	-	-	-	6.6
Bg1	76 – 94	45.2	13.8	15.5	25.5	0.57	1.3	0.16	0.41	0.3	0.9	0.33	7.3
Bg2	94 – 109	51.1	12.5	13.7	22.6	1.59	9.9	1.18	0.41	0.7	8.5	0.08	7.4
BCg	109 – 124	51.6	13.4	13.9	21.1	1.57	10.9	1.31	0.26	0.2	9.9	0.02	7.7
Cg1	124 – 150	49.7	15.4	15.0	19.9	1.23	10.3	1.23	-	0.9	8.7	0.10	8.1
Cg2	150 – 160	50.9	15.8	16.5	16.9	1.81	15.1	1.81	-	3.2	11.0	0.29	8.2
Cg3	160 – 208	48.3	16.9	18.2	16.7	1.86	15.5	1.86	-	4.0	10.6	0.04	8.2

GPS coordinates:

42.01.0967N 93.15.1826W

Soil descriptions for well 5 on Transect 1

Webster loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (2.5Y 2/0) loam; moderate medium subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) coatings on ped faces; many fine roots; 3% fine gravel; few fine stones; slightly acid; clear smooth boundary.
A2	18 – 28 cm; very dark grayish brown (2.5Y 3/2) clay loam; weak fine subangular blocky structure; friable; few fine dark brown (10YR 3/3) mottles; many fine very dark gray (2.5Y 3/1) coatings on ped faces; many fine roots; 3% fine gravel; few fine stones; moderately acid; clear smooth boundary.
AB	28 – 41 cm; olive brown (2.5Y 4/3) and very dark grayish brown (2.5Y 3/2) loam; weak fine subangular blocky structure; friable; common very dark gray (2.5Y 3/1) coatings on ped faces; few dark brown (7.5YR ¾) concretions; common fine roots; 3% fine gravel; few fine and medium stones; slightly acid; abrupt smooth boundary.
Bg1	41 – 53 cm; dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) loam; weak fine subangular blocky structure; friable; very dark gray (2.5Y 3/1) coatings on ped faces; few fine dark brown (7.5YR ¾) mottles; few fine roots; few fine and medium stones; 3% fine gravel; slightly acid; clear smooth boundary.
Bg2	53 – 76 cm; dark grayish brown (2.5Y 4/2) loam; moderate fine prismatic structure; friable; few fine dark yellowish brown (10YR ¾) mottles; few fine black (N 2/0) coatings on ped faces; few fine light olive brown (2.5Y 5/4) mottles; few Mn concretions; few fine roots; few fine and medium stones; neutral; clear smooth boundary.
Bg3	76 – 89 cm; dark grayish brown (2.5Y 4/2) loam; moderate medium prismatic structure; friable; common fine light olive brown (2.5Y 5/4) mottles; few dark yellowish brown (10YR ¾) Fe concretions; few Mn concretions; few fine roots; slightly alkaline; clear smooth boundary.
Cg1	89 – 97 cm; grayish brown (2.5Y 5/2) and dark grayish brown (2.5Y 4/2) loam; massive; friable; many fine light olive brown (2.5Y 5/4) mottles; few fine yellowish brown (10YR 5/6 & 5/8) mottles; few medium dark brown (7.5YR ¾) Fe concretions; few Mn concretions; few fine roots; many fine stones; few medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	97 – 127 cm; grayish brown (2.5Y 5/2) loam; massive; friable; common medium light olive brown (2.5Y 5/4) mottles; few fine and medium dark brown (7.5YR ¾) Fe concretions; few Mn concretions; common fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.

Horizon	Soil Description
Cg3	127 – 155 cm; grayish brown (2.5Y 5/2) loam; massive; friable; many fine light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine dark brown (7.5YR ¾) mottles; common fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg4	155 – 175 cm; grayish brown (2.5Y 5/2) loam; massive; friable; common medium light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; common Mn concretions; common fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg5	175 – 196 cm; grayish brown (2.5Y 5/2) loam; massive friable; many fine to medium light olive brown (2.5Y 5/4) mottles; common fine strong brown (7.5YR 5/8) mottles; few Mn concretions; many fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 5 on transect 1 in Colo Bog.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 18	29.8	21.7	22.0	26.4	2.31	-	-	2.31	-	-	-	5.3
A2	18 – 28	33.4	18.7	19.8	28.1	1.26	-	-	1.26	-	-	-	5.8
AB	28 – 41	42.7	15.5	15.7	26.1	0.73	-	-	0.73	-	-	-	6.2
Bw	41 – 53	47.9	14.4	14.1	23.6	0.48	-	-	0.48	-	-	-	6.4
Bg1	53 – 76	50.5	13.6	14.4	21.4	0.21	1.6	0.19	0.21	0.1	1.4	0.07	7.0
Bg2	76 – 89	50.8	14.1	14.9	20.2	0.27	3.1	0.37	0.27	0.7	2.2	0.32	7.5
Cg1	89 – 97	51.0	14.8	15.8	18.4	1.06	8.9	1.06	-	0.9	7.3	0.12	8.0
Cg2	97 – 127	49.4	15.9	17.0	17.6	1.75	14.6	1.75	-	2.9	10.7	0.27	8.1
Cg3	127 – 155	49.9	15.4	17.9	16.9	1.98	16.5	1.98	-	4.0	11.5	0.35	8.2
Cg4	155 – 175	48.6	15.5	19.8	16.0	2.01	16.7	2.01	-	4.0	11.8	0.34	8.3
Cg5	175 – 196	48.9	16.5	17.9	16.7	3.52	29.4	3.52	-	3.2	24.0	0.13	8.3

GPS Coordinates:

42.01.0986N 93.15.2148W

Soil descriptions for well 6 on transect 1

Webster clay loam   Upland Prairie   Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 8 cm; black (N 2/0) clay loam; weak fine subangular blocky structure; friable; many fine roots; 2% fine gravel; neutral; abrupt smooth boundary.
A2	8 – 25 cm; black (2.5Y 2/0) loam; moderate fine subangular blocky structure; friable; many fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
A3	25 – 48 cm; black (2.5Y 2/0) clay loam; weak fine subangular blocky structure; friable; many fine roots; 2% fine gravel; neutral; clear smooth boundary.
Bg1	48 – 71 cm; very dark gray (2.5Y 3/1) clay loam; moderate medium subangular blocky structure; friable; common fine roots; 2% fine gravel; neutral; clear smooth boundary.
Bg2	71 – 84 cm; very dark gray (5Y 3/1) and dark gray (5Y 4/1) loam; weak fine prismatic structure; friable; few fine olive gray (5Y 5/2) Fe depletions; few fine roots; 2% fine gravel; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
BCg	84 – 107 cm; very dark gray (5Y 3/1) and dark gray (5Y 4/1) silt loam; moderate medium prismatic structure; firm; common fine light olive gray (5Y 6/2) Fe depletions; few fine and medium dark yellowish brown (10YR 4/6) mottles; few Mn oxides; few fine roots; few fine and medium stones; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; clears smooth boundary.
Cg	107 – 112 cm; light olive gray (5Y 6/2) and dark gray (5Y 4/1) loam; massive; firm; few black (2.5Y 2/1) krotovinas; few fine dark yellowish brown (10YR 4/6) mottles; few fine roots; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg1	112 – 132 cm; light olive gray (5Y 6/2) and dark gray (5Y 4/1) loam; massive; friable; many coarse dark yellowish brown (10YR 4/6) and olive brown (2.5Y 5/4) mottles; few Mn oxides; common fine stones; few medium and coarse stones; slight reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
2Cg2	132 – 168 cm; light olive gray (5Y 6/2), dark gray (5Y 4/1), and gray (5Y 5/1) loam; massive; friable; many coarse olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR ¾) fracture linings; few Mn oxides; strong reaction to 10% HCl; few fine to coarse stones; moderately alkaline; clear smooth boundary.
2Cg3	168 – 198 cm; gray (5Y 5/1) loam; massive; friable; common fine and medium olive brown (2.5Y 4/4) mottles; few dark yellowish brown (10YR ¾) fracture linings; few fine dark brown (7.5YYR ¾) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 6 on transect 1 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 8	35.3	19.7	16.1	28.8	4.27	1.8	0.21	4.06	0.5	1.1	0.45	7.3
A2	8 – 25	41.5	18.0	23.0	17.5	2.75	-	-	2.75	-	-	-	6.0
A3	25 – 48	29.9	18.7	21.8	29.6	1.97	-	-	1.97	-	-	-	6.7
Bg1	48 – 71	33.0	18.4	21.5	27.1	0.89	3.4	0.40	0.49	0.1	3.1	0.03	7.3
Bg2	71 – 84	36.0	18.7	20.5	24.8	0.62	1.8	0.21	0.41	0.3	1.4	0.21	7.8
BCg	84 – 107	31.5	19.7	33.9	15.0	0.84	5.2	0.62	0.22	0.9	4.0	0.23	8.0
Cg	107 – 112	31.4	17.7	25.3	25.5	1.19	9.9	1.19	-	0.7	8.5	0.08	8.0
2Cg1	112 – 132	52.0	16.5	16.0	15.6	1.72	14.4	1.72	-	2.8	10.7	0.26	8.1
2Cg2	132 – 168	51.2	17.7	16.8	14.3	2.23	18.6	2.23	-	3.8	13.6	0.28	8.3
2Cg3	168 – 198	49.0	15.0	18.6	17.3	2.25	18.7	2.25	-	5.1	12.5	0.41	8.2

GPS Coordinates:

42.01.1006N 93.15.2422W

Soil descriptions for well 7 on transect 1

Canisteo loam Pond Depression Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 25 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; few fine and medium light olive gray (5Y 6/2) masses; many fine roots; few fine stones; slightly alkaline; clear smooth boundary.
A2	25 – 43 cm; black (N 2/0) loam; moderate fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) and dark gray (5Y 4/1) Fe depletions; 5% fine gravel; common fine roots; few fine stones; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
A3	43 – 61 cm; black (N 2/0) loam/clay loam; moderate medium subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; few fine dark gray (5Y 4/1) Fe depletions; few fine roots; few fine stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg1	61 – 86 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silty clay loam; massive; firm; few fine olive brown (2.5Y 4/4) mottles; few fine roots; few fine to coarse stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg2	86 – 109 cm; 90% gray (5Y 5/1) and dark gray (5Y 4/1) and 10% black (N 2/0) clay loam; massive; firm; many fine olive brown (2.5Y 4/4) mottles; common fine yellowish brown (10YR 5/8) mottles; few dark brown (7.5YR ¾) pore linings; few fine and medium stones; moderately alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
2Cg	109 – 127 cm; gray (5Y 5/1) and dark gray (5Y 4/1) sandy loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; common fine stones; few medium stones; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg	127 – 152 cm; gray (5Y 5/1) and dark gray (5Y 4/1) sandy loam; massive; friable; many fine to medium olive brown (2.5Y 4/4) mottles; common fine yellowish brown (10YR 5/8) mottles; few fine dark brown (7.5YR ¾) mottles; few fine and medium stones; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
4Cg	152 – 175 cm; dark grayish brown (2.5Y 4/2) and dark gray (5Y 4/1) sandy loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; few fine dark brown (7.5YR ¾) mottles; few black (N 2/0) krotovinas; common fine stones; few medium and coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
5Cg	175 – 203 cm; dark gray (5Y 4/1) loam; massive; friable; few coarse olive brown (2.5Y 4/4) mottles; few fine dark brown (7.5YR ¾) mottles; common fine stones; few medium and coarse stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 7 on transect 1 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 25	34.8	18.1	21.5	25.5	3.98	6.5	0.77	3.21	3.1	3.1	1.0	7.5
A2	25 – 43	31.5	18.2	24.3	26.0	2.24	4.3	0.51	1.73	1.1	2.9	0.38	7.7
A3	43 – 61	27.0	19.9	26.2	26.9	0.96	1.8	0.21	0.75	0.3	1.4	0.21	7.7
Bg1	61 – 86	16.4	20.2	32.5	31.0	0.67	3.6	0.43	0.24	0.7	2.7	0.26	7.6
Bg2	86 – 109	24.9	22.6	24.0	28.5	1.22	9.4	1.13	0.09	0.2	8.5	0.02	7.7
2Cg	109 – 127	71.5	6.9	8.9	12.7	1.17	10.3	1.24	-	0.9	8.7	0.10	7.9
3Cg	127 – 152	55.0	10.0	14.9	20.1	1.58	12.1	1.46	-	0.8	10.4	0.08	7.9
4Cg	152 – 175	65.0	9.1	11.6	14.3	1.27	11.8	1.42	-	1.7	9.3	0.18	8.1
5Cg	175 – 203	51.3	15.0	16.9	16.8	1.97	15.8	1.85	-	2.3	12.1	0.19	7.9

GPS Coordinates:

42.01.1011N 93.15.2666W

Soil descriptions for well 8 on transect 1

Canisteo-Okoboji loam Pond Depression Footslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; common fine platy dark grayish brown (2.5Y 4/1) Fe depletions; many fine roots; 5% fine gravel; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
A2	18 – 41 cm; black (2.5Y 2/0) loam; moderate medium subangular blocky structure; friable; many fine dark brown (7.5YR ¾) mottles; few fine and medium olive gray (5Y 5/2) Fe depletions; many fine roots; 2-5% fine gravel; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
A3	41 – 76 cm; black (2.5Y 2/0) silt loam; moderate medium subangular blocky structure; friable; few fine roots; 2% fine gravel; few fine and medium stones; slightly alkaline; abrupt smooth boundary.
A4	76 – 94 cm; black (2.5Y 2/0) loam; moderate fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) mottles; 5% fine gravel; few fine and medium stones; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2A5	94 – 114 cm; black (2.5Y 2/0) silty clay loam; massive; friable; few fine platy olive brown (2.5Y 4/4) mottles; 2% fine gravel; faint reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2A6	114 – 137 cm; black (2.5Y 2/0) silty clay loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; many coarse gray (5Y 5/1) Fe depletions; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Bg	137 – 165 cm; gray (5Y 5/1) silty clay loam; massive; friable; many fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Ckg	165 – 206 cm; gray (5Y 5/1) silt loam; massive; friable; common fine olive brown (2.5Y 4/4) mottles; few fine dark brown (7.5YR ¾) and dark yellowish brown (10YR 4/6) mottles; common $CaCO_3$ threads; violent reaction to 10% HCl; moderately alkaline.

Characterization data for well 8 on transect 1 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 18	38.4	17.0	20.1	24.5	3.62	5.1	0.61	3.01	1.3	3.5	0.37	7.8
A2	18 – 41	35.3	18.6	20.4	25.7	4.12	4.9	0.58	3.54	2.0	2.6	0.77	7.8
A3	41 – 76	21.8	23.7	28.0	26.4	2.75	1.8	0.21	2.54	0.1	1.6	0.06	7.5
A4	76 – 94	30.6	19.4	24.0	26.0	2.47	7.1	0.85	1.62	1.5	5.2	0.29	8.0
2A5	94 – 114	7.4	24.3	36.0	32.3	1.23	2.0	0.24	0.99	0.1	1.8	0.06	7.6
2A6	114 – 137	6.8	20.8	39.4	33.0	1.07	3.3	0.40	0.60	0.5	2.6	0.19	7.9
2Bg	137 – 165	8.1	22.7	38.0	31.3	1.52	12.6	1.52	-	0.8	10.9	0.07	7.8
2Ckg	165 – 206	8.9	26.7	38.9	25.6	2.27	18.9	2.27	-	5.5	12.4	0.44	8.0

GPS Coordinates:

42.01.1021N 93.15.2783W

Soil Descriptions for well 1 on transect 2

Clarion loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Typic Hapludoll

Horizon	Soil Description
A1	0 –10 cm; black (2.5Y 2/1) loam; weak fine granular structure; friable; many fine roots; 2% fine gravel; slightly acid; clear smooth boundary.
A2	10 – 33 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; many fine and very fine roots; 2% fine gravel; strongly acid; clear smooth boundary.
A3	33 – 46 cm; black (10YR 2/1) clay loam; weak fine subangular blocky structure; friable; 5% fine gravel; moderately acid; abrupt smooth boundary.
A4	46 – 53 cm; black (10YR 2/1) clay loam; weak fine granular structure; friable; common fine roots; 5% fine gravel; moderately acid; abrupt smooth boundary.
Bw1	53 – 64 cm; very dark grayish brown (10YR 3/2) clay loam; weak fine subangular blocky structure; friable; common black (10YR 2/1) coatings on ped faces; common fine roots; 2-5% fine gravel; few fine and medium stones; slightly acid; clear smooth boundary.
Bw2	64 – 89 cm; dark brown (10YR 3/3) loam; moderate fine subangular blocky structure; friable; few black (10YR 2/1) coatings on ped faces; common fine roots; 2% fine gravel; few fine and medium stones; slightly acid; gradual smooth boundary.
BCg	89 – 109 cm; olive brown (2.5Y 4/4) loam; weak fine subangular blocky structure; friable; few fine dark brown (7.5YR ¾) mottles; 2% fine gravel; few fine roots; few fine and medium stones; neutral; clear smooth boundary.
Cg1	109 – 122 cm; olive brown (2.5Y 4/4) loam; moderate fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2), grayish brown (2.5Y 5/2), and dark brown (7.5YR ¾) mottles; few fine stones; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg1	122 – 130 cm; olive brown (2.5Y 4/4) loam; massive; friable; few fine grayish brown (2.5Y 5/2) and dark grayish brown (2.5Y 4/2) mottles; black (2.5Y 2/0) krotovinas; few fine $CaCO_3$ concretions; few fine roots; few fine stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg2	130 – 147 cm; olive brown (2.5Y 4/4) loam; massive; friable; few medium grayish brown (2.5Y 5/2) mottles; few fine yellowish brown (10YR 5/8) and dark brown (7.5YR ¾) mottles; Mn concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.

Horizon	Soil Description
Ckg2	147 – 175 cm; olive brown (2.5Y 4/4) loam; massive; friable; common medium grayish brown (2.5Y 5/2) mottles; few fine yellowish brown (10YR 5/8) and dark brown (7.5YR ¾) mottles; Mn concretions; few fine stones; many fine CaCO3 streaks; violent reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg3	175 – 196 cm; olive brown (2.5Y 4/4) and light olive brown (2.5Y 5/4) sandy loam; massive; friable; few fine grayish brown (2.5Y 5/2) mottles; few fine yellowish brown (10YR 5/8) and dark brown (7.5YR ¾) mottles; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 1 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 10	33.5	21.0	20.7	24.7	2.73	-	-	2.73	-	-	-	6.1
A2	10 – 33	27.7	20.6	23.1	28.7	2.48	-	-	2.48	-	-	-	5.4
A3	33 – 46	26.7	20.2	22.7	30.3	1.93	-	-	1.93	-	-	-	5.7
A4	46 – 53	31.7	19.1	20.7	28.4	1.73	-	-	1.73	-	-	-	6.0
Bw1	53 – 64	37.7	16.8	17.4	28.1	0.90	-	-	0.90	-	-	-	6.1
Bw2	64 – 89	45.2	14.6	14.8	25.4	0.39	-	-	0.39	-	-	-	6.2
BCg	89 – 109	48.2	12.3	15.9	23.6	0.39	-	-	0.39	-	-	-	7.0
Cg1	109 – 122	49.5	12.6	16.4	21.4	0.18	2.0	0.24	0.18	0.3	1.6	0.19	7.8
Ckg1	122 – 130	48.2	14.3	17.6	19.9	1.75	12.9	1.55	-	2.6	9.5	0.27	7.6
Cg2	130 – 147	49.1	13.7	19.2	17.9	1.75	14.9	1.79	-	2.3	11.7	0.20	8.2
Ckg2	147 – 175	38.4	12.5	23.7	25.4	2.42	20.2	2.42	-	4.8	14.2	0.34	8.2
Cg3	175 – 196	62.4	13.9	13.0	10.8	1.91	16.0	1.92	-	2.9	12.0	0.24	8.3

GPS Coordinates:

42.00.4961N 93.16.1543W

Soil descriptions for well 2 on transect 2

Delft loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Hapludoll

Horizon	Soil Description
A1	0 – 15 cm; black (2.5Y 2/1) loam; weak fine subangular blocky structure; friable; many fine and very fine roots; 2% fine gravel; moderately acid; clear smooth boundary.
A2	15 – 30 cm; black (2.5Y 2/1) loam; moderate medium subangular blocky structure; friable; many fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
A3	30 – 53 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; many fine roots; 5% fine gravel; slightly acid; clear smooth boundary.
A4	53 –66 cm; black (2.5Y 2/1) loam; weak fine subangular blocky structure; frible; common fine very dark grayish brown (10YR 3/2) masses; few fine yellowish brown (10YR 5/8) mottles; common fine roots; 5% fine gravel; few fine stones; slightly acid; clear smooth boundary.
Bg1	66 – 84 cm; dark brown (10YR 3/3) loam; moderate fine subangular blocky structure; friable; common black (10YR 2/1) coatings on ped faces; few fine yellowish brown (10YR 5/8) mottles; common fine roots; few fine stones; 2% fine gravel; neutral; clear smooth boundary,
Bg2	84 –104 cm; dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) loam; moderate medium subangular blocky structure; friable; very dark gray (10YR 3/1) coatings on ped faces; few medium yellowish brown (10YR 5/8) mottles; few fine roots; few fine and medium stones; neutral; clear smooth boundary.
Cg1	104 –114 cm; light olive brown (2.5Y 5/4) loam; massive; friable; common fine dark grayish brown (2.5Y 5/2) mottles; common fine yellowish brown (10YR 5/8) mottles; few fine roots; few fine stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg1	114 – 142 cm; light olive brown (2.5Y 5/6) and olive brown (2.5Y 4/4) loam; massive; friable; few fine grayish brown (2.5Y 5/2) mottles; few fine and medium strong brown (7.5YR 5/6) mottles; common fine $CaCO_3$ streaks; common fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Ckg2	142 – 175 cm; olive brown (2.5Y 4/4) loam; massive; friable; common medium grayish brown (2.5Y 5/2) mottles; few fine strong brown (7.5YR 5/6) mottles; few fine and medium stones; few fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	175 – 196 cm; olive brown (2.5Y 4/4) loam; massive; friable; few fine grayish brown (2.5Y 5/2) mottles; few fine strong brown (7.5YR 5/8) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 2 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dol. %	Ratio	pH
A1	0 – 15	30.5	23.6	21.8	24.2	3.19	-	-	3.19	-	-	-	5.8
A2	15 – 30	29.7	21.8	21.9	26.6	2.58	-	-	2.58	-	-	-	5.7
A3	30 – 53	32.8	19.7	20.1	27.3	2.12	-	-	2.12	-	-	-	6.1
A4	53 – 66	36.4	16.8	20.2	26.6	1.42	-	-	1.42	-	-	-	6.3
Bg1	66 – 84	42.1	15.6	17.3	25.0	0.53	-	-	0.53	-	-	-	6.6
Bg2	84 – 104	46.9	15.1	16.2	21.7	0.29	1.3	0.16	0.13	0.1	1.1	0.09	7.2
Cg1	104 – 114	48.2	17.6	16.5	17.7	0.96	8.0	0.96	-	1.6	5.9	0.27	8.0
Ckg1	114 – 142	47.7	17.2	18.9	16.2	2.08	17.3	2.08	-	4.0	12.3	0.33	8.0
Ckg2	142 – 175	46.6	18.0	19.3	16.1	2.18	18.2	2.18	-	6.3	11.0	0.57	8.3
Cg2	175 – 196	46.3	18.1	19.4	16.3	1.79	14.9	1.79	-	3.4	10.6	0.32	8.3

GPS Coordinates:

42.00.5127N 93.16.1504W

Soil descriptions of well 3 on transect 2

Delft loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (2.5Y 2/0) loam; weak fine granular structure; friable; many fine roots; 2% fine gravel; strongly acid; clear smooth boundary.
A2	18 – 30 cm; black (2.5Y 2/1) loam; moderate fine subangular blocky structure; friable; many fine roots; 5% fine gravel; very strongly acid; clear smooth boundary.
A3	30 – 58 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; many fine roots; 5% fine gravel; few fine very dark grayish brown (2.5Y 3/2) mottles; moderately acid; clear smooth boundary.
A4	58 – 76 cm; very dark gray (2.5Y 3/0) clay loam; moderate fine subangular blocky structure; friable; common fine roots; 5% fine gravel; common fine very dark grayish brown (2.5Y 3/2) mottles; slightly acid; clear smooth boundary.
Bg1	76 – 86 cm; very dark gray (2.5Y 3/1) and dark grayish brown (2.5Y 4/2) loam; moderate fine subangular blocky structure; slightly firm; few fine dark grayish brown (10YR ¾) mottles; few fine roots; 2% fine gravel; few fine and medium stones; slightly acid; clear smooth boundary.
Bg2	86 – 107 cm; dark grayish brown (2.5Y 4/2) loam; moderate medium subangular blocky structure; friable; few very dark gray (2.5Y 3/1) coatings on ped faces; few fine yellowish brown (10YR 5/8) mottles; few fine roots; few fine and medium stones; 2% fine gravel; neutral; clear smooth boundary.
Cg1	107 – 122 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few fine yellowish brown (10YR 5/8) mottles; common fine Mn concretions; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	122 – 135 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few fine yellowish brown (10YR 5/8) mottles; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg3	135 – 165 cm; grayish brown (2.5Y 5/2) loam; massive; friable; many fine yellowish brown (10YR 5/8) mottles; few Mn concretions; few strong brown (7.5YR 4/6) Fe concretions; 2% fine gravel; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg4	165 – 183 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few medium yellowish brown (10YR 5/6 and 5/8) mottles; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline.

Characterization Data for well 3 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 18	33.3	22.1	21.4	23.2	3.52	-	-	3.52	-	-	-	5.5
A2	18 – 30	31.0	22.5	22.3	24.2	2.97	-	-	2.97	-	-	-	5.0
A3	30 – 58	31.0	18.9	21.7	28.3	1.90	-	-	1.90	-	-	-	5.8
A4	58 – 76	35.1	17.7	18.7	28.5	1.00	-	-	1.00	-	-	-	6.1
Bg1	76 – 86	37.2	13.6	22.7	26.4	0.58	-	-	0.58	-	-	-	6.5
Bg2	86 – 107	40.2	18.5	16.9	24.3	0.39	1.3	0.16	0.23	0.1	1.1	0.09	7.1
Cg1	107 – 122	41.9	21.4	15.8	21.0	0.94	7.8	0.94	-	0.5	6.7	0.07	8.0
Cg2	122 – 135	47.0	17.6	16.2	19.1	1.18	9.9	1.18	-	0.2	8.9	0.02	8.0
Cg3	135 – 165	46.3	15.7	20.4	17.6	2.07	17.3	2.07	-	4.9	11.4	0.43	8.2
Cg4	165 – 183	42.9	18.9	21.9	16.3	1.92	16.0	1.92	-	2.7	12.3	0.22	8.2

GPS Coordinates:

42.00.5352N 93.16.1445W

Soil descriptions for well 4 on transect 2

Delft loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (2.5Y 2/0) clay loam; weak fine subangular blocky structure; friable; many fine roots; 2% fine gravel; slightly acid; clear smooth boundary.
A2	15 – 30 cm; black (2.5Y 2/0) clay loam; weak medium subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) mottles; many fine roots; 2-5% fine gravel; neutral; clear smooth boundary.
A3	30 – 48 cm; black (2.5Y 2/0) clay loam; moderate medium subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) and dark grayish brown (2.5Y 4/2) mottles; many fine roots; 5% fine gravel; neutral; clear smooth boundary.
A4	48 –66 cm; black (5Y 2/1) clay loam; moderate fine subangular blocky structure; friable; few medium dark grayish brown (2.5Y 4/1) mottles; common fine roots; 2-5% fine gravel; neutral; clear smooth boundary.
Bg	66 – 79 cm; very dark gray (2.5Y 3/1) clay loam; moderate fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) mottles; few fine yellowish brown (10YR 5/8) mottles; few fine roots; few fine stones; 2% fine gravel; neutral; clear smooth boundary.
2BCg	79 – 99 cm; grayish brown (2.5Y 5/2) sandy loam; moderate fine prismatic structure; friable; very dark gray (2.5Y 3/1) coatings on ped faces; few fine roots; few fine stones; moderately alkaline; clear smooth boundary.
2Cg	99 – 112 cm; grayish brown (2.5Y 5/2) sandy loam; massive; friable; friable; few very dark gray (2.5Y 3/1) coatings on ped faces; common fine yellowish brown (10YR 5/8) mottles; dark brown (7.5YR ¾) Fe concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
3Cg	112 – 137 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few fine yellowish brown (10YR 5/8) and olive brown (2.5Y 4/4) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
4Cg	137 – 191 cm; grayish brown (2.5Y 5/2) clay loam; massive; friable; common medium olive brown (2.5Y 4/4) mottles; few fine yellowish brown (10YR 5/8) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
5Cg	191 – 221 cm; grayish brown (2.5Y 5/2) loam; friable; common medium olive brown (2.5Y 4/4) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 4 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 15	26.5	20.0	24.6	28.8	3.98	-	-	3.98	-	-	-	6.3
A2	15 – 30	25.4	19.0	24.3	31.3	2.73	-	-	2.73	-	-	-	6.6
A3	30 – 48	26.9	17.2	24.8	31.1	1.29	-	-	1.29	-	-	-	6.8
A4	48 – 66	25.6	16.9	25.7	31.8	0.66	-	-	0.66	-	-	-	6.8
Bg	66 – 79	31.7	17.1	20.8	30.5	0.45	2.6	0.32	0.13	0.7	1.8	0.39	7.3
2BCg	79 – 99	54.9	11.9	12.3	20.9	0.33	1.5	0.19	0.14	0.1	1.3	0.08	7.5
2Cg	99 – 112	52.8	13.9	12.2	21.1	0.39	2.9	0.35	0.04	0.5	2.2	0.23	7.9
3Cg	112 – 137	44.4	13.7	17.5	24.3	0.99	8.3	0.99	-	0.01	7.6	0.00	8.0
4Cg	137 – 191	36.2	13.2	22.2	28.3	1.60	13.3	1.60	-	2.3	10.1	0.23	8.1
5Cg	191 – 221	49.9	15.1	18.2	16.8	2.21	18.4	2.21	-	3.1	14.1	0.22	8.3

GPS Coordinates:

42.00.5566N 93.16.1475W

Soil descriptions for well 5 on transect 2

Canisteo loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; common fine roots; 5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	23 – 46 cm; black (2.5Y 2/0) clay loam; moderate medium subangular blocky structure; friable; few medium dark grayish brown (2.5Y 4/1) mottles; common fine roots; 5% fine gravel; slight reactin to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg1	46 – 53 cm; grayish brown (2.5Y 5/2) and dark grayish brown (2.5Y 4/2) loam; moderate fine subangular blocky structure; friable; few black (2.5Y 2/0) coatings on ped faces; few fine dark yellowish brown (10YR 4/6) mottles; few fine roots; few fine stones; 2-5% fine gravel; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg2	53 – 74 cm; grayish brown (2.5Y 5/2) sandy loam/loam; moderate fine subangular blocky structure; friable; common fine dark yellowish brown (10YR 4/6) mottles; few black (2.5Y 2/0) coatings on ped faces; few fine roots; few fine stones; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg3	74 – 86 cm; grayish brown (2.5Y 5/2) loam; moderate fine subangular blocky structure; friable; few fine dark yellowish brown (10YR 4/6) mottles; few fine faint dark grayish brown (2.5Y 4/2) masses; few fine stones; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg	86 – 107 cm; dark grayish brown (2.5Y 5/2) and very dark gray (5Y 3/1) clay loam; massive; friable; black (2.5Y 2/0) krotovinas; few Mn concretions; few fine olive brown (2.5Y 4/4) mottles; common fine strong brown (7.5YR 5/8) mottles; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
2Cg1	107 – 122 cm; gray (5Y 5/1) loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; common fine dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/8) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
2Cg2	122 – 137 cm; gray (5Y 5/1) loam; massive; friable; many fine dark yellowish brown (10YR 4/4 and 4/6) mottles; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg3	137 – 160 cm; gray (5Y 5/1) loam; massive; friable; few medium olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
2Cg4	160 – 175 cm; gray (5Y 5/1) and very dark gray (N 3/0) loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; common fine strong brown (7.5YR 4/6) mottles; few Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg5	175 – 213 cm; gray (5Y 5/1) and grayish brown (2.5Y 5/2) loam; massive; friable; few fine dark yellowish brown (10YR 4/6) mottles; few fine Mn concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 5 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 23	34.3	19.8	18.2	27.6	3.34	2	0.24	3.10	0.3	1.6	0.19	7.7
A2	23 – 46	26.9	27.8	17.2	28.1	0.84	2	0.21	0.63	0.5	1.1	0.45	7.8
Bg1	46 – 53	45.1	15.7	14.8	24.4	0.52	3	0.35	0.17	0.3	2.5	0.12	8.0
Bg2	53 – 74	52.6	14.2	11.3	21.9	0.83	6	0.73	0.10	0.6	5.0	0.12	8.0
Bg3	74 – 86	39.8	18.4	19.3	22.5	0.98	8	0.95	-	0.3	7.0	0.04	8.1
Cg	86 – 107	27.1	18.2	27.8	26.9	1.46	13	1.50	-	2.4	9.3	0.26	8.2
2Cg1	107 – 122	42.4	17.3	22.4	17.8	2.25	17	2.04	-	3.1	12.8	0.24	8.3
2Cg2	122 – 137	39.7	22.3	25.5	12.6	2.23	19	2.23	-	4.4	13.0	0.34	8.3
2Cg3	137 – 160	35.4	25.5	26.5	12.6	2.19	18	2.15	-	2.7	14.1	0.19	8.3
2Cg4	160 – 175	35.2	16.2	25.4	23.3	1.90	15	1.75	-	3.2	10.4	0.31	8.2
2Cg5	175 – 213	40.6	22.5	24.1	12.8	2.33	20	2.39	-	2.8	15.8	0.18	8.2

GPS Coordinates:

42.00.5605N 93.16.1523W

Soil descriptions for well 6 on transect 2

Okoboji silty clay loam Sedge Pond Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 28 cm; black (2.5Y 2/0) silty clay loam; moderate medium subangular blocky structure; friable; many fine roots; 2% fine gravel; neutral; clear smooth boundary.
A2	28 – 53 cm; black (2.5Y 2/0) clay loam; moderate medium subangular blocky structure; friable; few fine and medium very dark grayish brown (2.5Y 3/2) mottles; few fine olive brown (2.5Y 4/4) mottles; many fine roots; 2% fine gravel; slightly alkaline; clear smooth boundary.
A3	53 – 74 cm; black (2.5Y 2/0) clay loam; moderate medium subangular blocky structure; firm; common fine dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) mottles; few medium gray (5Y 5/1) Fe depletions; common fine roots; 2% fine gravel; slightly alkaline; clear smooth boundary.
Bg	74 – 91 cm; gray (5Y 5/1) clay loam; moderate fine prismatic structure; firm; few fine olive brown (2.5Y 5/6) mottles; many fine olive brown (2.5Y 4/4) mottles; few fine and medium stones; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
BCg	91 – 112 cm; gray (5Y 5/1) and dark gray (5Y 4/1) loam; moderate medium prismatic structure; firm; few fine dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; few fine and medium stones; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg1	112 – 140 cm; dark gray (5Y 4/1) sandy loam; massive; friable; common medium olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; fe fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg2	140 – 155 cm; gray (5Y 5/1) loam; massive; friable; many medium olive brown (2.5Y 4/4) mottles; few strong brown (7.5YR 4/6) Fe concretions; few Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
2Cg3	155 – 168 cm; olive brown (2.5Y 4/4) and light olive brown (2.5Y 5/4) sandy loam; massive; friable; few fine gray (5Y 5/1) Fe depletions; few coarse strong brown (7.5YR 4/6) Fe concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
3Cg	168 – 198 cm; dark grayish brown (2.5Y 4/2), very dark grayish brown (2.5Y 3/2), and olive brown (2.5Y 4/4) loam; massive friable; few medium gray (5Y 5/1) Fe depletions; few dark yellowish brown (10YR 3/6) fracture linings; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 6 on transect 2 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 28	15.2	21.5	28.9	34.4	4.00	-	-	4.00	-	-	-	6.8
A2	28 – 53	22.2	18.2	26.0	33.6	1.18	1	0.16	1.02	0.3	0.9	0.33	7.4
A3	53 – 74	26.7	18.2	24.3	30.8	0.81	2	0.21	0.60	0.5	1.1	0.45	7.4
Bg	74 – 91	32.2	16.6	23.6	27.5	0.96	7	0.86	0.10	0.1	6.5	0.02	7.8
BCg	91 – 112	39.8	14.5	23.4	22.2	1.77	14	1.64	-	1.9	10.8	0.18	8.0
2Cg1	112 – 140	53.7	14.3	17.2	14.8	2.28	18	2.16	-	3.7	13.1	0.28	8.2
2Cg2	140 – 155	51.4	14.4	18.4	15.7	2.13	18	2.17	-	6.2	10.9	0.57	8.2
2Cg3	155 – 168	54.7	16.0	17.6	11.8	2.73	19	2.29	-	4.9	13.1	0.37	8.2
3Cg	168 – 198	42.6	15.6	20.5	21.3	1.58	11	1.34	-	2.0	8.4	0.24	8.0

GPS Coordinates:

42.00.5718N 93.16.1660W

Soil descriptions for well 1 on transect 3

Nicollet loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (10YR 2/1) loam; moderate fine subangular blocky structure; friable; many fine roots; common medium roots; 5% fine gravel; moderately acid; clear smooth boundary.
A2	18 –33 cm; very dark gray (10YR 3/1) loam; weak fine subangular blocky structure; friable; 5% fine gravel; common fine roots; few fine stones; moderately acid; clear smooth boundary.
A3	33 – 53 cm; very dark gray (10YR 3/1) loam; weak fine subangular blocky structure; friable; few fine very dark grayish brown (10YR 3/2) masses on ped faces; common fine roots; 5% fine gravel; few fine to coarse stones; moderately acid; clear smooth boundary.
ABg	53 – 64 cm; very dark gray (10YR 3/1) loam; moderate fine subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; common fine dark grayish brown (2.5Y 4/2) mottles; few fine roots; few fine stones; 2% fine gravel; neutral; clear smooth boundary.
Bg	64 – 81 cm; dark grayish brown (2.5Y 4/2) sandy loam; moderate fine subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; few fine dark grayish brown (2.5Y 4/6) mottles; common fine very dark gray (10YR 3/1) coatings on ped faces; few fine roots; 2% fine gravel; common fine to coarse stones; moderately alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
Bkg	81 – 99 cm; olive gray (5Y 5/2) sandy loam; moderate fine subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; few fine dark grayish brown (10YR 4/6) mottles; very dark gray (10YR 3/1) krotovinas; few Mn concretions; few fine roots; few fine to coarse stones; few fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg	99 – 117 cm; olive gray (5Y 5/2) loam; massive; friable; common fine olive brown (2.5Y 4/4) mottles; few fine dark grayish brown (10YR 4/6) mottles; few fine yellowish red (5YR 4/6) Fe concretions; few Mn concretions; few fine to coarse stones; common $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg1	117 – 145 cm; olive brown (2.5Y 4/4) sandy loam; massive; friable; few fine olive gray (5Y 5/2) Fe depletions; few fine yellowish red (5YR 4/6) Fe concretions; few fine yellowish brown (10YR 5/4) mottles; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg2	145 – 226 cm; olive brown (2.5Y 4/4) sandy loam; massive; friable; few fine olive gray (5Y 5/2) Fe depletions; common Mn concretions; few fine yellowish brown (10YR 5/4) mottles; few fine to coarse sontes; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 1 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 18	40.3	19.1	18.4	22.2	2.50	-	-	2.50	-	-	-	5.7
A2	18 – 33	42.4	24.6	14.3	18.6	1.69	-	-	1.69	-	-	-	5.8
A3	33 – 53	44.7	17.5	16.1	21.7	1.09	-	-	1.09	-	-	-	6.0
ABg	53 – 64	49.0	14.3	15.5	21.2	0.72	-	-	0.72	-	-	-	6.7
Bg	64 – 81	55.2	12.6	14.0	18.2	2.96	24.6	2.96	-	9.4	14.1	0.67	7.9
Bkg	81 – 99	55.0	14.6	15.6	14.9	2.10	17.5	2.10	-	9.7	7.2	1.35	8.2
Ckg	99 – 117	50.5	15.9	17.1	16.4	2.27	18.9	2.27	-	6.6	11.3	0.58	8.2
Cg1	117 – 145	52.6	16.7	18.7	12.1	2.38	19.9	2.38	-	5.9	12.9	0.46	8.3
Cg2	145 – 226	54.1	15.6	16.6	13.7	2.09	17.4	2.09	-	4.7	11.7	0.40	8.3

GPS Coordinates:

42.00.7739N 93.16.2266W

Soil descriptions for well 2 on transect 3

Nicollet loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable;e many fine roots; common medium roots; 5% fine gravel; few fine and medium stones; moderately acid; clear smooth boundary.
A2	23 – 38 cm; very dark gray (N 3/0) loam; weak medium subangular blocky structure; friable; common fine very dark grayish brown (2.5Y 3/2) mottles; many fine roots; few fine stones; 5% fine gravel; neutral; clear smooth boundary.
Bw	38 – 56 cm; dark grayish brown (2.5Y 4/2) loam; moderate fine subangular blocky structure; friable; common fine very dark gray (2.5Y 3/1) coatings on ped faces; common fine roots; 2% fine gravel; few fine to coarse stones; slightly alkaline; clear smooth boundary.
Bg1	56 – 74cm; dark grayish brown (2.5Y 4/2) and dark gray (5Y 4/1) loam; modearate fine prismatic structure; few fine olive brown (2.5Y 4/4) mottles; few fine roots; few fine to coarse stones; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Bg2	74 – 89 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) loam; moderate fine prismatic structure; friable; few fine light olive brown (2.5Y 5/4) mottles; few fine roots; few fine to coarse stones; 2% fine gravel; few Mn concretions; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
BCg	89 – 107 cm; light olive gray (5Y 6/2) loam; moderate fine prismatic structure; friable; few fine dark gray (5Y 4/1) coatings on ped faces; few fine yellowish brown (10YR 5/4 & 5/6) mottles; few fine roots; few fine to coarse stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg	107 – 117 cm; light olive gray (5Y 6/2) loam; massive; friable; few fine yellowish brown (10YR 5/6) and olive brown (2.5Y 4/4) mottles; common fine Mn concretions; few medium dark gray (5Y 4/1) coatings on ped faces; common fine and medium $CaCO_3$ concretions; few fine roots; few fine and coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg1	117 – 127 cm; light olive gray (5Y 6/2) loam; massive; friable; common fine and medium olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg2	127 – 160 cm; olive brown (2.5Y 4/4) loam; massive; friable; few fine gray (5Y 5/1) Fe depletions; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
Cg3	160 – 224 cm; gray (5Y 5/1) and grayish brown (2.5Y 5/2) loam; massive; friable; many fine to medium olive brown (2.5Y 4/4) mottles; common fine Mn concretions; many fine dark brown (7.5YR ¾) and strong brown (7.5YR 4/6) Fe concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 2 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 23	37.8	18.9	19.8	23.5	2.62	-	-	2.62	-	-	-	6.0
A2	23 – 38	41.4	16.8	18.6	23.2	1.28	-	-	1.28	-	-	-	6.8
Bg1	38 – 56	42.7	17.5	18.7	21.0	0.55	2.4	0.29	0.26	0.5	1.8	0.28	7.5
Bg2	56 – 74	42.9	19.2	19.4	18.5	1.05	8.0	0.95	0.10	1.4	6.0	0.23	7.9
Bg3	74 – 89	45.9	18.8	18.6	16.7	1.50	12.5	1.50	-	4.8	7.1	0.68	8.2
BCg	89 – 107	43.4	21.6	20.8	14.2	2.19	18.3	2.19	-	5.5	11.7	0.47	8.3
Ckg	107 – 117	42.5	21.6	22.4	13.4	2.35	19.6	2.35	-	7.5	11.1	0.68	8.3
Cg1	117 – 127	40.3	26.7	21.7	11.3	2.20	18.4	2.20	-	4.4	12.8	0.34	8.3
Cg2	127 – 160	44.5	25.2	19.9	10.4	2.09	17.4	2.09	-	3.8	12.5	0.30	8.3
Cg3	160 – 224	49.2	18.7	17.6	14.4	2.00	16.7	2.00	-	3.8	11.9	0.32	8.2

GPS Coordinates:

42.00.7705N 93.16.2041W

Soil descriptions for well 3 on transect 3

Delft clay loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (N 2/0) clay loam; weak fine granular structure; friable; many fine and medium roots; 5% fine gravel; moderately acid; clear smooth boundary.
A2	18 – 36 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; common fine roots; few fine and medium stones; 2-5% fine gravel; slightly acid; clear smooth boundary.
A3	36 – 56 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) mottles; 2% fine gravel; few fine roots; few fine and medium stones; neutral; clear smooth boundary.
A4	56 – 74 cm; very dark gray (N 3/0) clay loam; moderate fine prismatic structure; friable; few fine and medium very dark grayish brown (2.5Y 3/2) mottles; few fine roots; few fine stones; 2% fine gravel; neutral; clear smooth boundary.
Bgl	74 – 89 cm; very dark gray (5Y 3/1) clay loam; moderarte fine prismatic structure; friable; firm; few fine olive gray (5Y 5/2) Fe depletions; few fine roots; few fine stones; 2% fine gravel; neutral; clear smooth boundary.
Bg2	89 – 104 cm; light olive gray (5Y 6/2) and dark gray (5Y 4/1) clay loam; moderate fine prismatic structure; firm; few fine to coarse stones; few fine roots; neutral; clear smooth boundary.
BCg	104 – 122 cm; light olive gray (5Y 6/2) and dark gray (5Y 4/1) loam; massive; friable; common fine dark yellowish brown (10YR 4/6) mottles; few fine olive brown (2.5Y 4/4) mottles; few fine Mn concretions; few fine and medium stones; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cgl	122 – 135 cm; gray (5Y 5/1) loam; massive; firm; few fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg2	135 – 157 cm; dark gray (5Y 4/1) loam; massive; friable; common fine dark yellowish brown (10YR 4/6) mottles; few fine olive brown (2.5Y 4/4) and yellowish brown (10YR 5/8); common fine Mn concretions; few fine stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg	157 – 203 cm; mixed very dark gray (N 3/0), dark gray (5Y 4/1), gray (5Y 5/1), and olive (5Y 4/3) loam; massive; friable; common fine dark yellowish brown (10YR 4/6) mottles; few fine and medium yellowish brown (10YR 5/8) mottles; few fine and medium stones; few fine to coarse $CaCO_3$ concretions; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 3 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 18	25.4	21.8	24.5	28.4	3.82	-	-	3.82	-	-	-	5.9
A2	18 – 36	21.8	20.4	26.2	31.7	3.03	-	-	3.03	-	-	-	6.2
A3	36 – 56	18.7	19.3	27.2	34.8	1.53	-	-	1.53	-	-	-	6.6
A4	56 – 74	20.5	18.7	25.7	35.1	0.96	-	-	0.96	-	-	-	6.8
Bg1	74 – 89	18.2	19.9	29.9	32.0	0.54	-	-	0.54	-	-	-	6.9
Bg2	89 – 104	22.3	23.7	26.6	27.4	0.38	2.2	0.27	0.11	0.5	1.6	0.31	7.2
BCg	104 – 122	46.9	17.3	14.9	20.9	0.69	5.4	0.64	0.05	0.4	4.6	0.09	7.9
Cg1	122 – 135	34.0	12.9	27.1	26.1	0.81	6.7	0.81	-	0.1	6.1	0.02	7.7
Cg2	135 – 157	36.5	12.8	25.2	25.5	1.10	9.2	1.10	-	0.2	8.2	0.02	7.8
Ckg	157 - 203	45.5	12.1	20.8	21.6	1.34	11.2	1.34	-	1.5	8.9	0.17	8.0

GPS Coordinates:

42.00.7710N 93.16.1797W

Soil descriptions for well 4 on transect 3

Delft-Canisteo loam Wet Prairie Zone I Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) loam; moderate fine subangular blocky structure; friable; few dark yellowish brown (10YR ¾) pore linings; many fine roots; 5% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	23 – 41 cm; black (2.5Y 2/0) clay loam; weak fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) mottles; common fine roots; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
A3	41 – 53 cm; very dark gray (N 3/0) clay loam; weak fine subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) mottles; few fine roots; 2% fine gravel; slight reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
A4	53 – 71 cm; very dark gray (10YR 3/1) clay loam; moderate fine subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) and olive (5Y 4/3) mottles; few fine roots; few fine stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
ABg	71 – 89 cm; black (N 2/0) and very dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) mottles; few fine roots; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg	89 – 104 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) clay loam; moderate fine prismatic structure; friable; very dark gray (N 3/0) coatings on ped faces; few fine stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg1	104 – 132 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) loam; massive; friable; few fine dark yellowish brown (10YR 4/6) and light olive brown (2.5Y 5/4) mottles; few Mn concretions; common fine CaCO3 threads; few medium stones; common fine stones; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg	132 – 155 cm; gray (5Y 5/1) and dark gray (5Y 4/1) loam; massive; friable; common fine and medium dark yellowish brown (10YR 4/6) mottles; few fine yellowish brown (10YR 5/8) and olive brown (2.5Y 4/4) mottles; very dark gray (5Y 3/1) coating on ped faces; strong reaction to 10% HCl; many fine and medium stones; moderately alkaline; clear smooth boundary.
Ckg2	155 – 175 cm; dark gray (5Y 4/1) loam; massive; friable; many fine dark yellowish brown (10YR 4/6) mottles; common fine dark brown (7.5YR ¾) mottles; few fine light olive brown (2.5Y 5/4) mottles; common fine CaCO3 threads; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg	175 – 203 cm; dark gray (5Y 4/1), gray (5Y 5/1), and olive brown (2.5Y 4/4) clay loam; massive; friable; few fine dark yellowish brown (10YR 4/6) mottles; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 4 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 23	29.7	21.2	22.2	26.8	3.65	9.5	1.14	2.51	0.2	8.5	0.02	7.7
A2	23 – 41	25.9	19.4	23.3	31.4	2.27	3.1	0.37	1.90	0.9	2.0	0.45	7.8
A3	41 – 53	23.0	19.7	24.8	32.4	1.29	2.2	0.27	1.02	0.3	1.8	0.17	7.9
A4	53 – 71	25.8	18.0	24.6	31.7	1.00	2.7	0.32	0.68	0.7	1.8	0.39	7.8
ABg	71 – 89	27.7	18.1	23.7	30.5	0.90	2.9	0.35	0.55	0.3	2.4	0.13	7.7
Bg	89 – 104	34.3	16.3	22.2	27.2	1.48	9.0	1.07	0.41	1.9	6.5	0.29	8.1
Ckg1	104 – 132	44.5	13.8	18.4	23.3	1.87	15.6	1.87	-	3.9	10.8	0.36	8.2
Cg	132 – 155	45.4	15.7	18.6	20.3	3.25	27.1	3.25	-	4.1	21.2	0.19	8.2
Ckg2	155 – 175	46.7	13.6	18.9	20.8	1.92	16.0	1.92	-	3.9	11.2	0.35	8.2
2Cg	175 – 203	33.5	10.0	17.6	39.0	1.87	15.6	1.87	-	5.3	9.5	0.56	8.2

GPS Coordinates:

42.00.7686N 93.16.1641W

Soil descriptions for well 5 on transect 3

Canisteo clay loam Wet Prairie Zone II Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) clay loam; weak medium subangular blocky structure; friable; common fine roots; 2% fine gravel; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
A2	23 – 38 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; few fine roots; 5% fine gravel; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
A3	38 – 48 cm; very dark gray (10YR 3/1) clay loam; moderate medium subangular blocky structure; firm; few fine roots; 2% fine gravel; black (N 2/0) coatings on ped faces; few fine CaCO3 masses; few fine olive brown (2.5Y 4/4) and dark grayish brown (2.5Y 4/2) mottles; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg1	48 – 61 cm; dark gray (5Y 4/1) clay loam; moderate medium subangular blocky structure; firm; few fine stone; few fine roots; 2% fine gravel; black (N 2/0) coatings on ped faces; few fine olive gray (5Y 5/2) Fe depletions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg2	61 – 76 cm; light olive gray (5Y 6/2) and very dark gray (5Y 3/1) clay loam; moderate medium subangular blocky structure; firm; few fine olive brown (2.5Y 4/4) mottles; black (N 2/0) coatings on ped faces; few fine roots; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg3	76 – 94 cm; light olive gray (5Y 6/2) and very dark gray (5Y 3/1) clay loam; moderate medium subangular blocky structure; firm; few fine strong brown (7.5YR 4/6), light olive brown (2.5Y 5/4), olive brown (2.5Y 4/4), and yellowish brown (10YR 5/8) mottles; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg	94 – 130 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; massive; friable; few fine and medium strong brown (7.5YR 4/6) mottles; few fine olive brown (2.5Y 4/4) mottles; few fine Mn concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
2Cg1	130 – 145 cm; gray (5Y 5/1) and dark gray (5Y 4/1) clay loam; massive friable; many fine dark yellowish brown (10YR 4/6) mottles; few fine Mn concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
2Cg2	145 – 157 cm; dark gray (5Y 4/1) and dark grayish brown (2.5Y 4/2) loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 5 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 23	28.5	18.3	23.3	29.9	4.71	11.1	1.33	3.38	6.1	4.6	1.33	7.9
A2	23 – 38	23.2	17.8	26.9	32.0	3.73	14.5	1.74	1.99	9.0	5.1	1.76	8.1
A3	38 – 48	22.5	18.7	27.8	31.0	1.89	10.2	1.22	0.67	3.6	6.0	0.60	8.2
Bg1	48 – 61	23.9	18.5	27.9	29.7	1.97	11.3	1.35	0.62	5.0	5.8	0.86	8.2
Bg2	61 – 76	25.2	19.5	27.5	27.8	2.05	15.5	1.86	0.19	4.6	10.1	0.46	8.3
Bg3	76 – 94	36.7	15.5	23.9	23.9	2.20	18.3	2.20	-	9.9	7.8	1.27	8.3
Cg	94 – 130	41.6	14.4	21.6	22.3	2.18	18.1	2.18	-	6.3	10.9	0.58	8.3
2Cg1	130 – 145	33.4	13.3	24.6	28.6	1.97	16.4	1.97	-	5.9	9.7	0.61	8.1
2Cg2	145 – 157	36.6	13.1	24.0	26.3	1.97	16.0	1.92	-	4.1	11.0	0.37	8.2

GPS Coordinates:

42.00.7690N 93.16.1309W

Soil descriptions for well 6 on transect 3

Glencoe loam Cattail Zone Footslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 13 cm; black (N 2/0) loam; moderate medium subangular blocky structure; friable; many fine roots; common medium roots; 5% fine grave;' slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	13 – 46 cm; black (N 2/0) loam; moderate medium subangular blocky structure; friable; many fine roots; few fine stones; 2-5% fine gravel; few fine dark yellowish brown (10YR 4/6) mottles; slightly alkaline; clear smooth boundary.
ABg	46 – 61 cm; very dark gray (N 3/0 & 5Y 3/1) clay loam; moderate medium subangular blocky structure; friable; common fine roots; few fine stones; few fine dark yellowish brown (10YR 4/6) mottles; slightly alkaline; clear smooth boundary.
Bg1	61 – 74 cm; very dark gray (N 3/0) clay loam; weak fine prismatic structure; friable; few fine grayish brown (2.5Y 5/2) Fe depletions; few fine roots; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg2	74 – 94 cm; olive gray (5Y 5/2) and dark gray (5Y 4/1) clay loam; weak fine prismatic structure; friable; black (N 2/0) krotovinas; few fine dark yellowish brown (10YR 4/6) mottles; few fine roots; few fine to coarse stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
BCg	94 – 122 cm; olive gray (5Y 5/2) and dark gray (5Y 4/1) loam; weak fine prismatic structure; friable; few fine dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/6); coarse dark yellowish brown (10YR 4/6) Fe concretions; very dark gray (2.5Y 3/0) krotovinas; few fine to coarse stones; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg	122 – 165 cm; olive gray (5Y 5/2) and dark gray (5Y 4/1) loam; massive; friable; common fine dark yellowish brown (10YR 4/6) mottles; few fine yellowish brown (10YR 5/6), strong brown (7.5YR 4/6), and dark brown (7.5YR ¾) mottles; few fine Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 6 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 13	37.1	19.5	19.5	23.9	3.66	3	0.35	3.31	0.5	2.2	0.23	7.6
A2	13 – 46	31.4	21.1	21.3	26.2	2.45	2	0.21	2.24	0.5	1.1	0.45	7.3
ABg	46 – 61	31.5	18.7	22.3	27.6	0.76	1	0.16	0.60	0.1	1.1	0.09	7.4
Bg1	61 – 74	33.4	15.9	22.8	27.9	0.69	2	0.24	0.45	0.5	1.4	0.36	7.6
Bg2	74 – 94	37.4	13.7	21.3	27.6	0.38	1	0.13	0.25	0.1	0.9	0.11	7.7
BCg	94 – 122	46.4	15.6	16.8	21.2	0.32	2	0.19	0.13	0.3	1.1	0.27	7.9
Cg	122 – 165	42.4	17.9	20.9	18.7	1.30	11	1.27	-	0.2	9.6	0.02	8.1

GPS Coordinates:

42.00.7686N 93.16.1211W

Soil descriptions for well 7 on transect 3

Canisteo loam Wet Prairie Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 13 cm; black (N 2/0) loam; moderate medium subangular blocky structure; friable; many fine roots; 5% fine gravel; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
A2	13 – 25 cm; black (N 2/0) loam; moderate medium subangular blocky structure; friable; common fine roots; 5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	25 – 41 cm; very dark gray (2.5Y 3/1) loam; moderate fine prismatic structure; friable; few fine roots; 5% fine gravel; common black (N2/0) coatings on ped faces; few fine dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) mottles; few fine roots; 5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg1	41 – 53 cm; very dark gray (5Y 3/1) and dark grayish brown (2.5Y 4/2) loam; moderate fine prismatic structure; friable; few fine dark yellowish brown (10YR 4/6) and grayish brown (2.5Y 5/2) mottles; few fine roots; few fine stones; 5% fine gravel; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Bg2	53 – 64 cm; light olive gray (5Y 6/2) and olive gray (5Y 5/2 & 4/2) sandy loam; moderate fine prismatic structure; friable; few fine dark yellowish brown (10YR 4/6) mottles; few fine very dark gray (5Y 3/1) coatings on ped faces; few fine roots; few fine stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg1	64 – 76 cm; light olive gray (5Y 6/2), gray (5Y 5/1), and olive gray (5Y 5/2) loamy sand; loose; many fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few medium stones; common fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg2	76 – 137 cm; gray (5Y 6/1 & 5/1) loamy sand/sand; loose; few fine olive brown (2.5Y 4/4), dark yellowish brown (10YR 4/6 & ¾) mottles; few Mn oxides; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 7 on transect 3 in Colo Bog.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 13	46.6	18.9	15.6	18.9	3.34	3	0.40	2.94	0.7	2.4	0.29	7.6
A2	13 – 25	42.0	20.2	17.4	20.4	2.80	3	0.32	2.48	0.3	2.2	0.14	7.7
A3	25 – 41	46.6	15.3	16.5	21.6	1.63	5	0.61	1.02	2.2	2.6	0.85	7.8
Bg1	41 – 53	50.7	13.4	16.8	19.1	1.08	6	0.72	0.36	1.0	4.5	0.22	8.0
Bg2	53 – 64	65.3	10.4	11.5	12.9	1.12	9	1.09	0.03	2.3	6.3	0.37	8.1
Cg1	64 – 76	75.9	9.0	6.8	8.3	1.38	11	1.33	-	2.7	7.7	0.35	8.3
Cg2	76 – 137	83.9	6.8	4.1	5.2	1.10	10	1.14	-	2.9	6.0	0.48	8.4

GPS Coordinates:

42.00.7729N 93.16.1104W

APPENDIX B. SOIL DESCRIPTIONS AND CHARACTERIZATION DATA FOR WELLS IN HARRIER'S MARSH COMPLEX

Soil descriptions for well 1 on transect 1

Clarion loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 13 cm; black (10YR 2/1) loam; weak fine granular structure; friable; many medium to fine roots; 5% fine gravel; neutral; clear smooth boundary.
A2	13 – 30 cm; black (10YR 2/1) loam; moderate fine subangular blocky structure; friable; many fine roots; 5% fine gravel; few fine stones; slightly acid; abrupt smooth boundary.
A3	30 – 43 cm; black (10YR 2/1) clay loam; moderate fine subangular blocky structure; friable; few fine faint very dark grayish brown (10YR 3/2) mottles; many fine roots; 2% fine gravel; few fine stones; abrupt smooth boundary.
Bw	43 – 61 cm; dark brown (10YR 3/3) loam; moderate fine subangular blocky structure; friable; many fine roots; 2% fine gravel; few fine to medium stones; few very dark gray (10YR 3/1) coatings on ped faces; slightly alkaline; abrupt smooth boundary.
BCg	61 – 76 cm; olive brown (2.5Y 4/4) loam; weak fine subangular blocky structure; friable; few fine roots; 2% fine gravel; few fine and medium stones; few very dark gray (10YR 3/1) coatings on ped faces; few fine to medium prominent dark brown (7.5YR ¾) mottles; few fine distinct dark grayish brown (2.5Y 4/2) Fe depletions; slightly alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
Ckg1	76 – 114 cm; grayish brown (2.5Y 5/2) loam; moderate medium subangular blocky structure; friable; few fine roots; few medium to coarse stones; few fine to medium $CaCO_3$ concretions; common fine $CaCO_3$ streaks; common medium distinct olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; few fine dark brown (7.5YR ¾) concretions; common Mn oxides; slightly alkaline; strong reaction to 10% HCl; abrupt smooth boundary.
Ckg2	114 – 173 cm; light olive brown (2.5Y 5/4) loam; massive; friable; few fine roots; very few $CaCO_3$ streaks; few fine to coarse stones; few fine prominent (10YR 4/6) dark yellowish brown (10YR 4/6) mottles; few medium distinct light brownish gray (2.5Y 6/2) Fe depletions; few dark brown (7.5YR ¾) concretions; few Mn oxides; slightly alkaline; strong reaction to 10% HCl; gradual smooth boundary.
Cg	173 – 244 cm; light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) loam; massive; friable; few fine to coarse stones; few medium to coarse distinct light brownish gray (2.5Y 6/2) Fe depletions; few dark brown (7.5YR ¾) concretions; slightly alkaline; strong reaction to 10% HCl.

Characterization data for well 1on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 13	35.6	19.5	21.5	23.4	5.00	19.5	2.34	2.66	2.1	16.0	0.13	7.5
A2	13 – 30	30.9	19.5	22.7	26.9	2.39	-	-	2.39	-	-	-	6.3
A3	30 – 43	28.1	19.9	24.1	27.9	1.95	-	-	1.95	-	-	-	6.8
Bw	43 – 61	32.9	17.0	24.0	26.1	0.93	2.5	0.29	0.64	0.1	2.2	0.05	7.4
BCg	61 – 76	51.1	13.3	15.6	20.0	1.68	13.1	1.58	0.10	1.2	11	0.11	7.9
Ckg1	76 – 114	51.4	14.8	17.4	16.4	2.39	19.9	2.39	-	6.4	12.5	0.51	8.5
Ckg2	114 – 173	49.9	14.9	19.1	16.1	2.53	21.0	2.53	-	6.8	13.1	0.52	8.6
Cg	173 – 244	51.2	14.9	18.3	15.6	2.18	18.1	2.18	-	4.9	12.2	0.40	8.4

GPS Coordinates:

42.01.3906N   94.00.5371W

Soil descriptions for well 2 on transect 1

Clarion loam Upland Prairie Shoulder Slope Position
Fine-loamy, mixed, superactive, mesic Typic Hapludoll

Horizon	Soil Description
A1	0 – 23 cm; black (10YR 2/1) loam; weak fine subangular blocky structure; friable; many fine and medium roots; 5% fine gravel; slightly acid; clear smooth boundary.
A2	23 – 43 cm; very dark gray (10YR 3/1) clay loam; moderate fine subangular blocky structure; friable; dark brown (10YR 3/3) coatings on ped faces; few dark grayish brown (10YR 4/2) root depletions; many fine roots; 2-5% fine gravel; few very fine stones; slightly acid; abrupt smooth boundary.
Bw	43 – 61 cm; brown (10YR 4/3) loam; moderate fine subangular blocky structure; friable; common fine roots; 2% fine gravel; few very fine stones; very dark gray (10YR 3/1) coatings on ped faces; neutral; clear smooth boundary.
BCg	61 – 74 cm; olive brown (2.5Y 4/4) sandy loam; moderate fine subangular blocky structure; friable; few fine dark grayish brown (2.5Y 4/2) mottles; few fine dark yellowish brown (10YR 4/6) mottles; very dark gray (10YR 3/1) and black (N 2/0) coatings on ped faces; few fine roots; 2% fine gravel; few fine stones; slightly alkaline; abrupt smooth boundary.
Cg	74 – 84 cm; grayish brown (2.5Y 5/2) sandy loam; weak fine subangular blocky structure; friable; few fine dark yellowish brown (10YR 4/6) mottles; few fine yellowish brown (10YR 5/6) and light olive brown (2.5Y 5/4) mottles; few Mn concretions; few fine roots; few fine to medium stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Ckg1	84 – 114 cm; grayish brown (2.5Y 5/2) loam; moderate medium subangular blocky structure; friable; common fine olive brown (2.5Y 4/5) and light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; dark brown (7.5YR ¾) concretions; few fine roots; few fine to medium stones; many fine $CaCO_3$ streaks; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg2	114 – 137 cm; grayish brown (2.5Y 5/2) loam; massive; friable; black (N 2/0) krotovinas; few fine dark yellowish brown (10YR 4/6) mottles; common fine light olive brown (2.5Y 5/4) mottles; dark brown (7.5YR ¾) concretions; common $CaCO_3$ streaks; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg3	137 – 203 cm; light brownish gray (2.5Y 6/2) and grayish brown (2.5Y 5/2) loam; massive; friable; many fine to medium light olive brown (2.5Y 5/4) mottles; common medium dark yellowish brown (10YR 4/6) mottles; few Mn concretions; dark brown (7.5YR ¾) concretions; black (N 2/0) krotovinas; very few $CaCO_3$ streaks; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 2 on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 23	41.7	18.5	17.1	22.7	2.13	-	-	2.13	-	-	-	6.3
A2	23 – 43	34.5	18.3	19.4	27.8	1.47	-	-	1.47	-	-	-	6.2
Bw	43 – 61	45.6	14.2	15.8	24.5	1.02	3.4	0.41	0.62	0.2	2.9	0.07	7.0
BCg	61 – 74	52.6	14.3	14.1	19.0	2.56	17.3	2.08	0.48	0.8	15.2	0.05	7.5
Cg	74 – 84	52.4	16.1	15.3	16.2	1.90	13.7	1.64	-	2.6	10.2	0.25	8.0
Ckg1	84 – 114	48.5	16.2	18.2	17.0	2.25	22.8	2.73	-	6.8	14.7	0.46	8.2
Ckg2	114 – 137	48.9	17.4	17.3	16.4	2.08	18.2	2.19	-	5.8	11.4	0.51	8.2
Ckg3	137 – 203	51.6	16.2	16.8	15.5	2.08	23.6	2.83	-	6.0	16.2	0.37	8.3

GPS Coordinates:

42.01.4175N 94.00.5410W

Soil descriptions for well 3 on transect 1

Webster loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (2.5Y 2/1) loam; weak fine subangular blocky structure; friable; many fine to medium roots; 5% fine gravel; moderately acid; clear smooth boundary.
A2	15 – 33 cm; black (2.5Y 2/1) loam; moderate fine subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) mottles; moderate fine subangular blocky structure; friable; many fine roots; 2-5% fine gravel; moderately acid; clear smooth boundary.
A3	33 – 48 cm; very dark gray (2.5Y 3/1) loam; moderate fine subangular blocky structure; friable; few fine faint very dark grayish brown (2.5Y 3/2) mottles; 2-5% fine gravel; common fine roots; few fine to coarse stones; slightly acid; clear smooth boundary.
Bg	48 – 64 cm; dark grayish brown (2.5Y 4/2) loam; weak fine subangular blocky structure; friable; few fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) concretions; very dark gray (2.5Y 3/1) coatings on ped faces; few fine roots; few fine to coarse stones; 2% fine gravel; slightly alkaline; abrupt smooth boundary.
BCg	64 – 79 cm; dark grayish brown (2.5Y 4/2) loam; moderate fine subangular blocky structure; friable; common fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; very dark gray (10YR 3/1) coatings on ped faces; few fine roots; common fine to coarse stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg1	79 – 107 cm; grayish brown (2.5Y 5/2) and very gray (5Y 4/1) loam; weak fine prismatic structure; friable; common fine light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few fine dark brown (7.5YR ¾) concretions; very dark gray (10YR 3/1) coatings on ped faces; few fine roots; few fine to coarse stones; strong reaction to 10% HCL; slightly alkaline; clear smooth boundary.
Ckg1	107 – 122 cm; grayish brown (2.5Y 5/2) and gray (5Y 5/1) loam; massive; friable; few fine to medium light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; common $CaCO_3$ streaks; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Ckg2	122 – 175 cm; grayish brown (2.5Y 5/2) and gray (5Y 5/1) loam; massive; friable; common fine to medium light olive brown (2.5Y 5/4) mottles; common Mn concretions; few $CaCO_3$ streaks; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Cg2	175 – 218 cm; gray (5Y 5/1) loam; massive; friable; many fine to medium light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) mottles; very few fine strong brown (7.5YR 5/8) concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 3 on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 15	42.3	20.7	15.5	21.4	2.49	-	-	2.49	-	-	-	5.8
A2	15 – 33	37.3	21.0	16.7	24.9	2.11	-	-	2.11	-	-	-	6.0
A3	33 – 48	38.2	19.4	17.3	25.1	1.31	-	-	1.31	-	-	-	6.5
Bg	48 – 64	41.7	19.9	15.4	22.9	1.13	7.0	0.84	0.29	0.3	6.2	0.05	7.4
BCg	64 – 79	48.7	19.3	15.5	16.4	2.61	21.7	2.61	-	2.3	17.9	0.13	7.8
Cg1	79 – 107	50.8	15.7	17.0	16.5	2.39	19.9	2.39	-	6.0	12.8	0.47	8.2
Ckg1	107 – 122	48.7	16.2	17.9	17.2	2.85	23.8	2.85	-	7.9	14.6	0.54	8.2
Ckg2	122 – 175	50.4	16.6	17.2	15.8	3.18	26.5	3.18	-	6.2	18.7	0.33	8.2
Cg2	175 – 218	51.5	15.5	17.4	15.6	2.64	22.0	2.64	-	6.9	13.9	0.50	8.2

GPS Coordinates:

42.01.4331N 94.00.5420W

Soil descriptions for well 4 on transect 1

Canisteo clay loam Wetland Zone I Footslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (N 2/0) clay loam; moderate fine granular; friable; few medium roots; common fine roots; 5% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	18 – 33 cm; black (N 2/0) clay loam; moderate fine subangular blocky structure; friable; few fine to medium dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) Fe depletions; few fine roots; 2-5% fine gravel; common fine stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
A3	33 – 53 cm; black (N 2/0) clay loam; weak fine subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) and dark grayish brown (2.5Y 4/2) Fe depletions; fewfine roots; 2% fine fine gravel; few fine and medium stones; strong reaction 10% HCl; slightly alkaline; clear smooth boundary.
Bg1	53 – 66 cm; 60% very dark gray (N 3/0) and 40% dark gray (5Y 4/1) clay loam; moderate medium subangular blocky structure; friable; few fine roots; 2% fine gravel; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg2	66 – 81 cm; 70% dark gray (5Y 4/1) and 30% very dark gray (N 3/0) loam; moderate medium subangular blocky structure; friable; few fine dark yellowish brown (10YR 4/6) mottles; very few fine light olive brown (2.5Y 5/6) mottles; few fine roots; common fine stones; few medium and coarse stones; violent reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg	81 – 109 cm; gray (5Y 5/1) and olive gray (5Y 5/2) loam; weak fine prismatic structure; friable; many fine dark yellowish brown (10YR 4/6) mottles; common few to coarse stones; violent reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg1	109 – 135 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silty clay loam; massive; firm; few fine light olive brown (2.5Y 5/6) and olive brown (2.5Y 4/6) mottles; few Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Cg2	135 – 173 cm; gray (5Y 5/1) and dark gray (5Y 4/1) loam; massive; friable; common fine to medium light olive brown (2.5Y 5/6) and olive brown (2.5Y 4/6) mottles; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg	173 – 218 cm; light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) loam; massive; friable; few fine and medium gray (5Y 5/1) and dark gray (5Y 4/1) Fe depletions; dark yellowish brown (10YR 4/6) concentrations along fracture planes; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 4 on transect 1 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 18	31.1	16.4	22.9	29.5	4.21	8.1	0.97	3.24	1.9	5.7	0.33	7.9
A2	18 – 33	31.1	16.6	23.3	29.0	3.57	14.4	1.73	1.84	2.6	10.9	0.24	8.1
A3	33 – 53	28.9	18.3	23.1	29.7	2.55	8.3	0.99	1.56	2.6	5.2	0.50	8.2
Bg1	53 – 66	29.6	16.0	25.8	28.6	2.56	17.8	2.14	0.42	7.0	10.0	0.70	8.2
Bg2	66 – 81	40.1	13.7	22.4	23.9	2.57	19.3	2.32	0.25	9.5	9.1	1.04	8.3
Cg	81 – 109	46.7	13.9	18.8	20.5	2.54	21.2	2.54	-	9.2	11.0	0.84	8.3
2Cg1	109 – 135	35.3	16.6	20.9	27.1	0.97	8.1	0.97	-	2.1	5.5	0.38	8.1
2Cg2	135 – 173	38.7	16.2	20.8	24.3	2.31	19.3	2.31	-	4.9	13.3	0.37	8.3
3Cg	173 – 218	48.8	15.6	17.7	17.9	2.18	18.2	2.18	-	4.7	12.4	0.38	8.3

GPS Coordinates:

42.04.4541N 94.00.5439W

Soil descriptions for well 5 on transect 1

Canisteo clay loam Cattail Zone Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 10 cm; black (N 2/0) clay loam; weak fine subangular blocky structure; friable; many fine roots; few medium roots; moss litter on surface; 2% fine gravel; slightly alkaline; gradual smooth boundary.
A2	10 – 23 cm; black (N 2/0) clay loam; moderate fine subangular blocky structure; friable; common fine roots; 2% fine gravel; few fine stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	23 – 41 cm; very dark gray (N 3/0) clay loam; moderate medium subangular blocky structure; slightly firm; 2% fine gravel; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A4	41 – 56 cm; 70% very dark gray (N 3/0) and 30% very dark gray (10YR 3/1) clay loam; weak fine prismatic structure; slightly firm; few fine stones; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg	56 – 71 cm; 80% very dark gray (10YR 3/1) and 20% olive gray (5Y 5/2) loam; weak fine prismatic structure; firm; few fine and medium stones; few fine roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bkg	71 – 84 cm; dark gray (5Y 4/1) and olive gray (5Y 5/2) loam; moderate fine subangular blocky structure; firm; few coarse dark yellowish brown (10YR 4/6) mottles; black (N 2/0) krotovinas; few fine $CaCO_3$ concretions; few fine and medium stones; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg	84 – 114 cm; dark gray (5Y 4/1) and gray (5Y 5/1) loam; moderate fine prismatic structure; firm; few fine and medium dark yellowish brown (10YR 4/6) mottles; few fine to coarse $CaCO_3$ concretions; few fine roots; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Cg1	114 – 157 cm; dark gray (5Y 4/1) and gray (5Y 5/1) loam; massive; friable; common fine and medium dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; few fine Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg2	157 – 221 cm; olive brown (2.5Y 4/4) and light olive brown (2.5Y 5/4) loam; massive; friable; few fine dark gray (5Y 4/1) and gray (5Y 5/1) Fe depletions; few fine and medium Mn concretions; few fine dark yellowish brown (10YR 4/6) concentration along fractures; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 5 on transect 1 in Harrier's Marsh.

Horizon	Depth	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 10	28.8	18.8	24.1	28.2	4.06	3.6	0.43	3.63	0.70	2.7	0.26	7.5
A2	10 – 23	27.8	19.0	23.3	29.9	3.76	4.3	0.51	3.25	1.14	2.9	0.39	7.7
A3	23 – 41	32.0	16.3	21.7	30.0	1.39	2.7	0.32	1.07	0.50	2.0	0.25	7.8
A4	41 – 56	34.5	16.0	21.5	28.0	1.20	5.0	0.60	0.60	1.11	3.6	0.31	7.7
Bg	56 – 71	40.4	15.8	19.7	24.1	1.17	5.9	0.70	0.47	0.61	4.8	0.13	8.0
Bkg	71 – 84	47.3	15.6	16.9	20.2	1.90	15.8	1.90	-	2.51	12.2	0.21	8.0
Ckg	84 – 114	46.3	15.1	18.3	20.3	1.84	15.4	1.84	-	3.45	11.0	0.31	8.1
Cg1	114 – 157	49.8	15.3	18.1	16.8	2.38	19.9	2.38	-	4.89	13.8	0.35	8.3
Cg2	157 – 221	49.5	14.2	19.0	17.3	3.43	28.6	3.43	-	5.46	21.3	0.26	8.2

GPS Coordinates:

42.01.4624N 94.00.5410W

Soil descriptions for well 6 on transect 1

Canisteo clay loam Pond Depression Toeslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) clay loam; weak fine granular structure; friable; many fine roots; 2% fine gravel; slightly alkaline; clear smooth boundary.
A2	15 – 36 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; very few fine olive (5Y 4/3) mottles; common fine roots; 2% fine gravel; few fine stones; slightly alkaline; clear smooth boundary.
A3	36 – 53 cm; black (N 2/0) clay loam; weak fine prismatic structure; firm; few fine and medium olive (5Y 4/3) mottles; few fine roots; few fine stones; slightly alkaline; abrupt smooth boundary.
Bg	53 – 71 cm; very dark gray (N 3/0) and dark gray (5Y 4/1) clay loam; weak fine prismatic structure; firm; few fine roots; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
BCg	71 – 89 cm; dark gray (5Y 4/1) and olive gray (5Y 5/2) loam; moderate fine prismatic structure; firm; common fine olive brown (2.5Y 4/4) mottles; black (N 2/0) krotovinas; few fine dark yellowish brown (10YR 4/6) mottles; very few fine roots; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg1	89 – 135; dark gray (5Y 4/1) and olive gray (5Y 5/2) loam; massive; firm; common fine olive brown (2.5Y 4/4) and dark yellowish brown (10YR 4/6) mottles; few fine yellowish red (5YR 4/6) concretions; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg2	135 – 155 cm; mottled very dark gray (5Y 3/1); dark gray (5Y 4/1); and olive gray (5Y 5/2) loam; massive; friable; few medium olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg3	155 – 178 cm; dark gray (5Y 4/1) and gray (5Y 5/1) loam; massive; friable; common coarse olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few fine to coarse stones; strong reaction to 10% HCl; clear smooth boundary.
Cg4	178 – 208 cm; olive brown (2.5Y 4/4) and light olive brown (2.5Y 5/4) loam; massive; friable; few fine dark gray (5Y 4/1) Fe depletions; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 6 on transect 1 in Harrier's Marsh.

Horizon	Depth	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 15	22.7	18.7	25.3	33.3	3.81	4.8	0.57	3.24	0.65	3.8	0.17	7.3
A2	15 – 36	28.7	16.9	22.2	32.3	2.06	5.0	0.60	1.46	1.10	3.6	0.31	7.5
A3	36 – 53	35.5	13.6	19.6	31.2	1.13	3.2	0.38	0.75	0.48	2.5	0.19	7.5
Bg	53 – 71	31.9	15.4	21.1	31.6	0.92	5.0	0.59	0.33	1.10	3.6	0.31	7.6
BCg	71 – 89	46.4	13.1	17.7	22.9	-	12.2	1.47	-	0.58	10.7	0.05	7.9
Cg1	89 – 135	49.7	14.4	17.2	18.8	-	18.5	2.21	-	5.63	11.8	0.48	8.1
Cg2	135 – 155	45.1	14.1	16.7	24.2	-	9.7	1.17	-	0.68	8.3	0.08	8.0
Cg3	155 – 178	51.2	14.3	16.6	17.9	-	20.2	2.43	-	5.35	13.7	0.39	8.2
Cg4	178 – 208	51.8	14.2	17.0	17.1	-	25.0	3.00	-	5.16	18.3	0.28	8.2

GPS Coordinates:

42.01.4746N 94.00.5400W

Soil descriptions for well 7 on transect 1

Okoboji silty clay loam Pond Depression Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) silty clay loam; weak fine granular structure; friable; common fine roots; 2% fine gravel; slightly acid; gradual smooth boundary.
A2	15 – 36 cm; black (N 2/0) silty clay loam; moderate fine subangular blocky structure; friable; few fine roots; 2% fine gravel; neutral; clear smooth boundary.
A3	36 – 61 cm; black (N 2/0) silty clay loam; moderate fine prismatic structure; friable; few fine olive (5Y 4/3) mottles; few fine roots; neutral; gradual smooth boundary.
A4	61 – 84 cm; black (N 2/0) silty clay; moderate fine prismatic structure; firm; few fine prominent dark grayish brown (2.5Y 4/2) mottles; common roots sheaths; few fine roots; neutral; gradual smooth boundary.
AB	84 – 104 cm; black (N 2/0) and very dark gray (10YR 3/1) silty clay loam; moderate fine prismatic structure; firm; common fine prominent dark grayish brown (2.5Y 4/2) mottles; few fine roots; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
Cg1	104 – 122 cm; olive gray (5Y 5/2) and dark gray (5Y 5/1) silt loam; massive; firm; common fine olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg2	122 – 157 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silt loam; massive; friable; common fine and medium dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg3	157 – 208 cm; dark gray (5Y 4/1) silt loam; massive; friable; common medium prominent dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 7 on transect 1 in Harrier's Marsh.

Horizon	Depth	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 15	9.6	18.4	34.4	37.6	4.27	-	-	4.27	-	-	-	6.5
A2	15 – 36	11.6	17.9	33.8	36.7	3.13	-	-	3.13	-	-	-	6.8
A3	36 – 61	6.5	17.4	36.9	39.2	1.65	-	-	1.65	-	-	-	7.0
A4	61 – 84	6.7	14.6	37.5	41.2	1.61	3.5	0.42	1.19	1.6	1.8	0.89	7.2
AB	84 – 104	5.7	16.2	38.9	39.2	1.15	3.6	0.43	0.72	0.9	2.4	0.38	7.6
Cg1	104 – 122	8.9	17.4	50.6	23.1	1.21	5.5	0.67	0.54	2.0	3.3	0.60	7.6
Cg2	122 – 157	6.4	24.9	53.0	15.7	2.91	24.2	2.91	-	15.8	7.8	2.03	7.9
Cg3	157 – 208	8.3	19.2	52.3	20.2	2.29	19.1	2.29	-	5.3	12.7	0.42	7.9

GPS Coordinates:

42.01.4858N 94.00.5410W

Soil descriptions for well 1 on transect 2

Crippin loam Upland Prairie Shoulder Slope
Fine-loamy, mixed, superactive, calcareous, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 10 cm; black (10YR 2/1) loam; weak fine granular structure; friable; many fine to medium roots; few fine to medium stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	10 – 30 cm; black (10YR 2/1) loam; weak fine subangular blocky structure; friable; many fine roots; common medium roots; few fine to medium stones; 2% fine gravel; few fine yellowish brown (10YR 5/4) mottles; few medium to coarse carbonates; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
BA	30 – 53 cm; very dark gray (10YR 3/1) loam; moderate fine subangular blocky structure; friable; many fine roots; few fine stones; 2% fine gravel; few fine grayish brown (2.5Y 5/2) mottles; many fine to medium light olive brown (2.5Y 5/6 and 5/4) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bkg	53 – 79 cm; dark grayish brown (2.5Y 4/2) loam; weak fine subangular blocky structure; friable; common medium yellowish brown (10YR 5/4) mottles; few fine olive brown (2.5Y 4/4) mottles; few very fine strong brown (7.5YR 4/6) concretions; common fine roots; common medium to coarse $CaCO_3$ concretions; few fine to medium stones; strong reaction to 10% HCl; gradual smooth boundary.
BCkg	79 – 102 cm; light brownish gray (2.5Y 6/2) loam; moderate medium subangular blocky structure; friable; few fine to medium yellowish brown (10YR 5/4) mottles; few fine olive brown (2.5Y 4/4) mottles; few fine strong brown (7.5YR 4/6) and dark brown (7.5YR ¾) concretions; few fine to coarse $CaCO_3$ concretions; common CaCO3 streaks; few fine roots; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg	102 – 140 cm; light brownish gray (2.5Y 6/2) loam; massive; friable; few fine and medium light olive brown (2.5Y 5/4) mottles; common fine dark yellowish brown (10YR 4/6) mottles; few fine strong brown (7.5YR 5/8) concretions; common $CaCO_3$ streaks; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg	140 – 213 cm; brownish gray (2.5Y 5/2) loam; massive; friable; many fine to medium light olive brown (2.5Y 5/4) mottles; few medium and coarse dark yellowish brown (10YR 4/6) mottles; common Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 1 on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 10	48.6	14.9	15.9	20.6	2.93	4.3	0.51	2.42	1.13	2.9	0.39	7.5
A2	10 – 30	46.6	13.2	16.9	23.2	4.97	21.3	2.55	2.42	3.66	16.2	0.23	8.0
BA	30 – 53	45.1	13.7	19.4	21.8	2.77	16.2	1.95	0.82	7.05	8.5	0.83	8.3
Bkg	53 – 79	46.3	14.9	21.5	17.3	-	29.5	3.54	-	11.55	16.5	0.70	8.4
BCkg	79 – 102	50.1	14.1	19.5	16.3	-	21.8	2.62	-	7.05	13.6	0.52	8.5
Ckg	102 – 140	49.4	14.4	20.2	16.0	3.66	30.5	3.66	-	7.85	20.8	0.38	8.4
Cg	140 – 213	49.6	16.4	19.0	15.0	2.58	21.5	2.58	-	5.74	14.5	0.40	8.4

GPS Coordinates:

42.01.6543N   94.00.9297W

Soil descriptions for well 2 on transect 2

Canisteo loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; many fine and medium roots; few fine stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	15 – 28 cm; black (N 2/0) loam; moderate medium subangular blocky structure; friable; many fine roots; few fine stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	28 – 48 cm; black (N 2/0) loam; weak medium subangular blocky structure; friable; common fine roots; few fine and medium stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg	48 – 79 cm; very dark gray (N 3/0) loam; moderate medium subangular blocky structure; friable; few fine olive gray (5Y 4/2) mottles; common fine olive gray (5Y 5/2) mottles; few fine roots; few fine and medium stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Ckg	79 – 99 cm; olive gray (5Y 5/2) sandy loam; moderate medium subangular blocky structure; friable; few fine light olive brown (2.5Y 5/4) mottles; few fine and medium $CaCO_3$ concretions; few fine roots; few medium and coarse stones; common fine stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
2Cg	99 – 127 cm; light olive gray (5Y 6/2) sandy loam; massive; friable; few fine light olive brown (2.5Y 5/4) mottles; common medium and coarse dark yellowish brown (10YR 4/6) mottles; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg1	127 – 150 cm; dark gray (5Y 4/1) loam; massive; friable; many fine and medium dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg2	150 – 213 cm; dark grayish brown (2.5Y 4/2) loam; massive; friable; few fine dark yellowish brown (10YR 4/6), olive brown (2.5Y 4/4), and light olive brown (2.5Y 5/4) and mottles; few fine to coarse stones; few Mn concretions; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 2 on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 15	43.7	18.9	17.0	20.4	4.46	6.7	0.80	3.66	1.3	5.0	0.26	7.9
A2	15 – 28	41.0	17.2	19.3	22.5	5.79	19.0	2.28	3.51	1.0	16.6	0.06	7.7
A3	28 – 48	37.6	16.4	20.5	25.5	3.80	19.0	2.28	1.52	0.1	17.4	0.01	7.7
Bg	48 – 79	35.3	17.5	21.6	25.6	2.24	13.3	1.60	0.64	0.8	11.5	0.07	7.8
2Ckg	79 – 99	59.8	12.8	13.4	14.0	1.70	14.2	1.70	-	1.6	11.5	0.14	8.4
2Cg	99 – 127	55.4	14.3	15.6	14.7	2.53	21.1	2.53	-	3.0	16.7	0.18	8.3
3Cg1	127 – 150	47.7	13.3	19.6	19.3	1.93	16.0	1.93	-	2.9	12.1	0.24	8.2
3Cg2	150 – 213	43.8	14.9	21.2	20.1	2.68	22.3	2.68	-	5.2	15.8	0.33	8.2

GPS Coordinates:

42.01.6738N 94.00.9307W

Soil descriptions for well 3 on transect 2

Canisteo loam Wetland Zone I Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) loam; weak fine granular structure; friable; many fine to medium roots; 2% fine gravel; slightly alkaline; clear smooth boundary.
A2	15 – 33 cm; black (N 2/0) loam; moderate fine subangular blocky structure; friable; many fine roots; few medium roots; 2% fine gravel; few fine stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	33 – 53 cm; very dark gray (N 3/0) loam; weak medium subangular blocky structure; friable; sand lenses between ped faces; few fine roots; few fine and medium stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
AB	53 – 71 cm; very dark gray (N 3/0) loam; weak fine prismatic structure; firm; few fine olive gray (5Y 5/2) mottles; few fine olive (5Y 4/3) mottles; many dark brown (7.5YR 3/3) pore linings; few fine roots; few fine and medium stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg	71 – 91 cm; very dark gray (N 3/0 and 5Y 3/1) silty clay loam; weak fine prismatic structure; firm; few medium and coarse olive gray (5Y 5/2) mottles; many dark brown (7.5YR 3/3) pore linings; few fine roots; few fine stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg1	91 – 102 cm; dark gray (5Y 4/1) and olive gray (5Y 5/2) loam; weak fine subangular blocky structure; common fine olive brown (2.5Y 4/4) mottles; few dark brown (7.5YR 3/3) and strong brown (7.5YR 4/6) pore linings; few fine roots; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Cg2	102 – 119 cm; gray (5Y 5/1) silt loam; moderate medium subangular blocky structure; firm; common strong brown (7.5YR 4/6) pore linings; many fine olive brown (2.5Y 4/4) mottles; sand lenses between peds; few fine roots; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
2Cg3	119 – 142 cm; gray (5Y 5/1) loam; massive; friable; many fine dark brown (10YR 3/3) mottles; few strong brown (7.5YR 4/6) pore linings; sand lenses between ped faces; common dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg1	142 – 152 cm; gray (5Y 5/1) and very dark gray (N 3/0) loam; massive; friable; common fine dark brown (10YR 3/3) mottles; few fine olive brown (2.5Y 4/4) mottles; few strong brown (7.5YR 4/6) pore linings; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.

Horizon	Soil Description
3Cg2	152 – 173 cm; gray (5Y 5/1) loam; massive; friable; many fine olive brown (2.5Y 4/4) and dark yellowish brown (10YR 4/6) mottles; few dark brown (7.5YR 4/6) mottles; sand lenses between peds; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
4Cg	173 – 196 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silt loam; massive; friable; many fine olive brown (2.5Y 4/4) mottles; common fine dark yellowish brown (10YR 4/6) mottles; few fine dark brown (7.5YR 4/6) mottles; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 3 on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Ratio	pH
A1	0 – 15	37.7	20.6	20.4	21.4	4.48	2.9	0.35	4.13	0.5	2.2	0.23	7.5
A2	15 – 33	34.2	20.3	22.7	22.7	5.04	17.1	2.05	2.99	1.1	14.8	0.07	7.6
A3	33 – 53	40.2	18.9	19.5	21.3	2.95	17.0	2.04	0.91	1.5	14.3	0.10	7.8
AB	53 – 71	27.9	19.1	26.4	26.5	2.93	18.6	2.23	0.70	1.4	15.8	0.09	7.7
Bg	71 – 91	14.7	22.0	32.7	30.6	2.42	16.9	2.03	0.39	1.5	14.2	0.11	7.8
2Cg1	91 – 102	31.4	22.7	23.4	22.5	2.05	17.1	2.05	-	1.5	14.3	0.10	8.1
2Cg2	102 – 119	28.3	25.8	26.0	19.9	1.28	10.6	1.28	-	0.3	10.1	0.03	7.9
2Cg3	119 – 142	32.1	24.9	23.6	19.4	1.77	14.8	1.77	-	0.7	13.0	0.05	8.0
3Cg1	142 – 152	40.2	17.8	23.4	18.6	2.18	18.1	2.18	-	1.0	15.8	0.06	8.1
3Cg2	152 – 173	36.1	21.2	24.1	18.6	2.34	19.5	2.34	-	1.4	16.6	0.08	8.1
4Cg	173 – 196	20.0	27.4	33.5	19.1	2.36	19.6	2.36	-	1.9	16.3	0.12	8.1

GPS Coordinates:

42.01.6870N 94.00.9336W

Soil descriptions for well 4 on transect 2

Canisteo silt loam Cattail Zone Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) silt loam; weak fine subangular blocky structure; friable; many fine and medium roots; neutral; clear smooth boundary.
A2	15 – 41 cm; black (N 2/0) silt loam; weak fine subangular blocky structure; friable; many fine roots; few medium roots; few medium stones; slightly alkaline; clear smooth boundary.
A3	41 – 58 cm; very dark gray (N 3/0) silty clay loam; weak fine prismatic structure; firm; very few fine dark grayish brown (2.5Y 4/2) mottles; common fine roots; few medium roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg1	58 – 69 cm; very dark gray (N 3/0) silty clay loam; weak fine prismatic structure; firm; few dark brown (7.5YR 3/3) pore linings; few fine olive gray (5Y 5/2) mottles; few fine roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg2	69 – 84 cm; dark gray (5Y 4/1) and very dark gray (N 3/0) silty clay loam; moderate medium subangular blocky structure; firm; common dark brown (7.5YR 3/3) pore linings; few fine olive gray (5Y 5/2) mottles; few fine roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg1	84 – 112 cm; dark gray (5Y 4/1) and olive gray (5Y 5/2) silt loam; moderate medium subangular blocky structure; firm; many fine olive brown (2.5Y 4/4) mottles; few dark brown (7.5YR 3/3) pore linings; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg2	112 – 135 cm; gray (5Y 5/1) silt loam; massive; firm; common fine olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg3	135 – 157 cm; gray (5Y 5/1) silt loam; massive; friable; many fine dark yellowish brown (10YR 4/6) mottles; common fine olive brown (2.5Y 4/4) mottles; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Cg4	157 – 170 cm; very dark gray (N 3/0) and gray (5Y 5/1) silt loam; massive; friable; few fine dark brown (10YR 3/3) mottles; common fine dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	170 – 183 cm; dark gray (5Y 4/1), gray (5Y 5/1), and olive gray (5Y 5/2) loam; massive; friable; few fine dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.

Horizon	Soil Description
3Cg	183 – 213 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silt loam; massive; friable; few medium dark yellowish brown (10YR 4/4) mottles; many fine dark yellowish brown (10YR ¾) mottles; sand lenses between ped faces; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 4 on transect 2 in Harrier's Marsh.

Horizon	Depth	Sand	Coa. Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolomite	Rat.	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 15	17.8	25.0	32.6	24.6	6.07	3	0.35	5.72	0.3	2.5	0.12	7.2
A2	15 – 41	20.5	27.8	28.1	23.6	4.39	11	1.28	3.11	0.9	9.0	0.10	7.4
A3	41 – 58	10.9	26.7	31.6	30.8	1.31	2	0.24	1.07	0.3	1.6	0.19	7.7
Bg1	58 – 69	6.6	24.4	36.5	32.5	0.87	4	0.51	0.36	0.9	3.1	0.29	7.8
Bg2	69 – 84	1.9	22.8	40.1	35.2	0.40	3	0.32	0.08	0.5	2.0	0.25	7.9
Cg1	84 – 112	15.2	28.8	32.0	23.9	2.16	18	2.16	-	1.0	15.7	0.06	7.9
Cg2	112 – 135	26.3	26.7	27.7	19.3	1.92	16	1.92	-	0.6	14.2	0.04	7.9
Cg3	135 – 157	21.5	28.8	32.3	17.4	2.75	23	2.75	-	1.7	19.5	0.09	8.0
Cg4	157 – 170	13.4	21.8	42.1	22.8	2.08	17	2.08	-	1.7	14.3	0.12	8.1
2Cg	170 – 183	44.4	23.1	18.2	14.3	2.78	23	2.78	-	2.9	18.7	0.16	8.2
3Cg	183 – 213	28.9	25.1	27.8	18.2	3.55	30	3.55	-	3.8	23.7	0.16	8.2

GPS Coordinates:

42.01.6963N 94.00.9346W

Soil descriptions for well 5 on transect 2

Okoboji silty clay loam Pond Depression Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 18 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; many fine roots; neutral; gradual smooth boundary.
A2	18 – 43 cm; very dark gray (N 3/0) silty clay loam; moderate medium subangular blocky structure; friable; many fine roots; slightly alkaline; faint reaction to 10% HCl; clear smooth boundary.
A3	43 – 61 cm; very dark gray (N 3/0) silty clay loam; moderate medium subangular blocky structure; firm; few fine olive gray (5Y 5/2) mottles; few fine olive (5Y 4/3) mottles; very few very fine strong brown (7.5YR 4/6) pore linings; common fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
ABg	61 – 71 cm; 70% very dark gray (N 3/0) and 30% gray (5Y 5/1) silty clay loam; weak fine prismatic structure; firm; common fine dark yellowish brown (10YR 4/6 and 3/6) mottles; few fine roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg	71 – 89 cm; gray (5Y 5/1) silty clay loam; weak fine prismatic structure; firm; very dark gray (N 3/0) krotovinas; few fine and medium dark yellowish brown (10YR 4/6) mottles; common fine olive brown (2.5Y 4/3) and light olive brown (2.5Y 5/4) mottles; few fine dark brown (7.5YR 3/3) mottles; slight reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Ckg1	89 – 102 cm; olive (5Y 4/3) silt loam; massive; firm; few fine gray (5Y 5/1) and dark gray (5Y 4/1) Fe depletions; few fine yellowish brown (10YR 5/6) mottles; few $CaCO_3$ streaks; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg2	102 – 122 cm; olive (5Y 4/3) silt loam; massive; firm; few fine dark gray (5Y 4/1) and gray (5Y 5/1) Fe depletions; few fine dark yellowish brown (10YR 4/6) mottles; many $CaCO_3$ streaks; violent reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg3	122 – 140 cm; gray (5Y 5/1) silt loam; massive; friable; few fine dark yellowish brown (10YR 3/6) mottles; few fine and medium dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/6 and 5/8) mottles; common fine olive (5Y 4/3) mottles; few medium olive brown (2.5Y 4/4) mottles; few $CaCO_3$ concretions; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg1	140 – 150 cm; 70% gray (5Y 5/1) and 30% olive brown (2.5Y 4/4) loamy sand/sandy loam; loose; friable; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg2	150 – 183 cm; mixed olive (5Y 4/3 and 5/4), gray (5Y 5/1), and dark grayish brown (2.5Y 4/2) loamy sand/sandy loam; few fine dark yellowish brown (10YR 3/6 and 4/6) mottles; loose; strong reaction to 10% HCl; moderately alkaline

Characterization data for well 5 on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 18	16.0	22.4	32.9	28.7	6.79	3.4	0.40	6.39	0.7	2.5	0.28	7.2
A2	18 – 43	12.0	21.8	36.8	29.5	5.18	16.3	1.96	3.22	0.6	14.4	0.04	7.0
A3	43 – 61	13.5	17.2	36.8	32.5	1.10	14.9	1.79	1.10	0.1	13.7	0.01	7.4
ABg	61 – 71	3.4	18.9	42.8	34.9	1.02	15.8	1.90	1.02	0.9	13.7	0.07	7.6
Bg	71 – 89	6.4	22.9	39.4	31.3	0.82	7.4	0.89	0.07	0.5	6.3	0.08	7.8
Ckg1	89 – 102	11.0	24.5	38.7	25.7	2.27	18.9	2.27	-	3.1	14.6	0.21	8.0
Ckg2	102 – 122	11.1	23.4	39.5	26.0	2.43	20.3	2.43	-	6.4	12.7	0.50	8.0
Ckg3	122 – 140	11.0	22.1	42.2	24.6	3.08	25.7	3.08	-	9.2	15.2	0.61	8.1
2Cg1	140 – 150	74.5	14.7	4.7	6.2	1.61	13.4	1.61	-	2.8	9.8	0.29	8.5
2Cg2	150 – 183	79.3	11.1	4.5	5.1	2.37	19.8	2.37	-	3.5	15.0	0.23	8.5

GPS Coordinates:

42.01.7114N 94.00.9316W

Soil descriptions for well 6 on transect 2

Canisteo loam Cattail Zone Toeslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A	0 – 23 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; many fine roots; 5% fine gravel; few fine stones; slightly alkaline; abrupt smooth boundary.
AB	23 – 51 cm; very dark gray (N 3/0), dark gray (5Y 4/1), and light olive gray (5Y 6/2) loam; moderate medium subangular blocky structure; friable; common dark yellowish brown (10YR ¾) pore linings; few black (N 2/0) krotovinas; few fine roots; many fine stones; few medium and coarse stones; violent reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Bg	51 – 76 cm; light olive gray (5Y 6/2) silt loam; moderate medium subangular blocky structure; friable; many coarse yellowish brown (10YR 5/6) mottles; few black (N 2/0) krotovinas; common strong brown (7.5YR 4/6) pore linings; violent reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2BCg	76 – 94 cm; gray (5Y 5/1) silt loam; moderate medium subangular blocky structure; friable; few medium olive (5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	94 – 122 cm; gray (5Y 5/1) silt loam; massive; friable; many medium yellowish brown (10YR 5/6) mottles; few fine strong brown (7.5YR 4/6) pore linings; few fine olive (5Y 5/4) mottles; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
3Cg	122 – 145 cm; gray (5Y 5/1) silt loam; massive; friable; common coarse olive (5Y 5/4) mottles; few medium yellowish brown (10YR 5/6) mottles; common fine olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
4Cg	145 – 165 cm; mixed olive (5Y 5/4), olive brown (2.5Y 4/4), and gray (5Y 5/1) silt loam; massive; friable; few coarse yellowish brown (10YR 5/6) mottles; black (N 2/0) krotovinas; many fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
5Cg	165 – 201 cm; gray (5Y 5/1) loam; massive; friable; few medium olive brown (2.5Y 4/4) and olive (2.5Y 5/4) mottles; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 6 on transect 2 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A	0 – 23	40.5	20.7	20.1	18.7	4.74	3.1	0.37	4.37	0.2	2.6	0.08	7.5
AB	23 – 51	39.0	16.8	22.2	21.9	5.95	26.8	3.22	2.73	10.6	14.9	0.71	8.2
2Bg	51 – 76	14.5	27.5	39.6	18.3	-	31.5	3.77	-	17.1	13.2	1.30	8.2
2BCg	76 – 94	6.4	38.6	41.7	13.3	5.43	45.3	5.43	-	23.7	19.8	1.20	8.2
2Cg	94 – 122	2.1	11.9	66.7	19.3	2.83	23.6	2.83	-	5.3	16.9	0.31	8.2
3Cg	122 – 145	25.4	20.9	37.3	16.3	3.31	27.6	3.31	-	6.0	19.8	0.30	8.2
4Cg	145 – 165	36.2	21.4	29.3	13.0	2.63	22.0	2.63	-	5.6	15.1	0.37	8.3
5Cg	165 – 201	43.4	19.8	24.0	12.9	2.56	21.4	2.56	-	5.1	15.0	0.34	8.1

GPS Coordinates:

42.01.7295N 94.00.9307W

Soil descriptions for well 7 on transect 2

Canisteo loam Cattail Zone Toeslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 25 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; many fine roots; 5% fine gravel; neutral; abrupt smooth boundary.
A2	25 – 51 cm; black (N 2/0) and very dark gray (N 3/0 and 10YR 3/1) sandy loam; moderate medium subangular blocky structure; friable; few fine roots; many fine stones; few medium stones; few dark yellowish brown (10YR ¾) pore linings; few fine gray (5Y 5/1) Fe depletions; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg	51 – 86 cm; light brownish gray (5Y 6/2) silt loam; moderate medium subangular blocky structure; friable; common strong brown (7.5YR 4/6) pore linings; very dark gray (N 3/0) coatings on ped faces; common fine and medium yellowish brown (10YR 5/6) mottles; few fine roots; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	86 – 104 cm; gray (5Y 5/1) sandy loam; weak fine subangular blocky structure; friable; common fine olive brown (2.5Y 4/4) mottles; few strong brown (7.5YR 4/6) pore linings; few medium dark yellowish brown (10YR ¾) mottles; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg	104 – 117 cm; gray (5Y 5/1) loam; massive; friable; many medium yellowish brown (10YR 5/6 and 5/8) mottles; common fine olive brown (2.5Y 4/4) mottles; few fine stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
4Cg1	117 – 132 cm; dark grayish brown (2.5Y 4/2) and gray (5Y 5/1) loam; massive; friable; common fine olive brown (2.5Y 4/4) mottles; few medium light olive brown (2.5Y 5/4) mottles; few fine strong brown (7.5YR 4/6) and yellowish brown (10YR 5/6) mottles; few fine and medium stones; strong reaction to 10%HCl; slightly alkaline; abrupt smooth boundary.
4Cg2	132 – 150 cm; gray (5Y 5/1) loam; massive; friable; common medium olive brown (2.5Y 4/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few fine stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
5Cg	150 – 203 cm; dark grayish brown (2.5Y 4/2) sandy loam; massive; friable; few medium dark gray (5Y 4/1) mottles; few fine dark brown (7.5YR ¾) mottles; few fine stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 7 on transect 2 in Harrier's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolo.	Ratio	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 25	41.1	25.4	14.9	18.6	4.94	2.7	0.32	4.64	0.3	2.2	0.14	7.1
A2	25 – 51	55.3	18.5	11.2	15.1	0.87	14.5	1.74	0.87	0.7	12.7	0.06	7.7
Bg	51 – 86	31.1	27.9	24.3	16.7	2.45	19.0	2.29	0.16	3.0	14.8	0.20	7.9
2Cg	86 – 104	62.2	11.1	11.6	15.0	2.29	19.1	2.29	-	5.9	12.1	0.49	8.2
3Cg	104 – 117	35.1	13.4	27.7	23.8	2.42	20.1	2.42	-	7.4	11.7	0.63	8.0
4Cg1	117 – 132	49.3	14.2	20.1	16.3	2.89	24.1	2.89	-	8.4	14.5	0.58	8.0
4Cg2	132 – 150	45.9	14.1	22.4	17.6	2.24	18.7	2.24	-	5.2	12.4	0.42	8.1
5Cg	150 – 203	55.4	14.9	15.5	14.2	2.69	22.5	2.69	-	5.1	16.0	0.32	8.1

GPS Coordinates:

42.01.7383N   94.00.9336W

Soil descriptions for well 1 on transect 3

Clarion loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Typic Hapludoll

Horizon	Soil Description
A1	0 – 15 cm; very dark brown (10YR 2/2) loam; weak fine subangular blocky structure; friable; many fine roots; 2-5% fine gravel; strongly acid; clear smooth boundary.
A2	15 – 30 cm; very dark brown (10YR 2/2) loam; weak fine subangular blocky structure; friable; many fine roots; 5% fine gravel; slightly acid; clear smooth boundary.
A3	30 – 53 cm; very dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; friable; common fine very dark grayish brown (2.5Y 3/2) mottles; common fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
Bw1	53 – 74 cm; dark brown (10YR 3/3) clay loam; moderate fine subangular blocky structure; friable; few fine very dark gray (10YR 3/1) coatings on ped faces; common fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
Bw2	74 – 91 cm; brown (10YR 4/3) loam; weak fine subangular blocky structure; friable; few fine very dark gray (10YR 3/1) coatings on ped faces; few fine roots; few fine stones; 5% fine gravel; slightly acid; clear smooth boundary.
BCg	91 – 112 cm; dark grayish brown (2.5Y 4/2) loam; moderate medium subangular blocky structure; friable; few fine dark brown (7.5YR ¾) mottles; few black (2.5Y 2/0) coatings on ped faces; few fine roots; few fine stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	112 – 150 cm; brown (10YR 43) loamy sand; loose; friable; few fine dark brown (7.5YR ¾) mottles; many fine and medium stones; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
3Ckg	150 – 188 cm; brown (10YR 4/3) and light olive brown (2.5Y 5/4) loam; massive; friable; few coarse light brownish gray (2.5Y 6/2) Fe depletions; few fine dark brown (7.5YR ¾) mottles; few coarse $CaCO_3$ concretions; many fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
4Cg	188 – 200 cm; light olive brown (2.5Y 5/4) silt loam; massive; friable; few coarse light brownish gray (2.5Y 6/2) Fe depletions; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 1 on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo, %	Ratio	pH
A1	0 – 15	37.6	17.4	21.3	23.7	2.02	-	-	2.02	-	-	-	5.1
A2	15 – 30	34.7	17.1	22.4	25.7	1.94	-	-	1.94	-	-	-	5.3
A3	30 – 53	33.3	15.0	22.7	28.9	1.64	-	-	1.64	-	-	-	5.9
Bw1	53 – 74	36.1	15.0	20.6	28.3	1.12	-	-	1.12	-	-	-	5.9
Bw2	74 – 91	44.4	13.2	16.6	25.8	0.54	-	-	0.54	-	-	-	6.1
BCg	91 – 112	44.6	14.9	18.5	22.0	0.59	5.0	0.59	-	0.4	4.2	0.10	7.8
2Cg	112 – 150	76.8	8.8	7.2	7.2	3.22	26.8	3.22	-	4.3	20.7	0.21	8.4
3Ckg	150 – 188	42.8	9.7	32.5	15.1	3.49	29.1	3.49	-	10.6	17.0	0.62	8.3
4Cg	188 – 200	10.6	25.0	50.4	14.1	3.22	26.8	3.22	-	7.1	18.2	0.39	8.2

GPS Coordinates:

42.01.1694N 94.01.1133W

Soil descriptions for well 2 on transect 3

Clarion loam Upland Prairie Shoulder Position
Fine-loamy, mixed, superactive, mesic Typic Hapludoll

Horizon	Soil Description
A1	0 – 20 cm; black (10YR 2/1) loam; weak fine subangular blocky structure; friable; many fine roots; common medium roots; 5% fine gravel; slightly acid; abrupt smooth boundary.
A2	20 – 36 cm; brown (10YR 3/3) loam; weak fine subangular blocky structure; friable; few fine very dark gray (10YR 3/1) coatings on ped faces; many fine roots; few fine stones; 5% fine gravel; neutral; abrupt smooth boundary.
Bw	36 – 48 cm; dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; friable; few fine black (2.5Y 2/0) coatings on ped faces; few fine strong brown (7.5YR 4/6) mottles; many fine roots; few fie stones; 2-5% fine gravel; neutral; abrupt smooth boundary.
Bk	48 – 61 cm; light olive brown (2.5Y 5/4) loam; weak medium subangular blocky structure; friable; very few fine strong brown (7.5YR 4/6) concretions and mottles; common fine and medium $CaCO_3$ concretions; few fine roots; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2C	61 – 71 cm; light olive brown (2.5Y 5/4) sandy loam; weak fine subangular blocky structure; friable; few fine roots; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg1	71 – 99 cm; light olive brown (2.5Y 5/4) loam; moderate medium subangular blocky structure; friable; few fine and medium light brownish gray (2.5Y 6/2) Fe depletions; few fine strong brown (7.5YR 4/6) mottles; few fine yellowish brown (10YR 5/6) mottles; few fine roots; few fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Ckg	99 – 122 cm; olive brown (2.5Y 4/4) loam; massive; friable; few fine strong brown (7.5YR 4/6) and yellowish brown (10YR 5/6) mottles; few fine light brownish gray (2.5Y 6/2) Fe depletions; many medium to coarse $CaCO_3$ nodules; few fine and medium stones; few fine roots; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
3Cg2	122 – 135 cm; light olive brown (2.5Y 5/6) loam; massive; friable; few coarse light brownish gray (2.5Y 6/2) Fe depletions; few fine dark yellowish brown (10YR 4/6) and strong brown (7.5YR 4/6) mottles; few medium strong brown (7.5YR 5/8) concretions; few fine and medium stones; strong reaction to 10% HCl; slight alkaline; abrupt smooth boundary.
3Cg3	135 – 152 cm; light olive brown (2.5Y 5/4) loam; massive; friable; many medium light brownish gray (2.5Y 6/2) and brownish gray (2.5Y 5/2) Fe depletions; many fine dark yellowish brown (10YR 4/6) mottles; few fine strong brown (7.5YR 5/8) mottles; few fine Mn concretions; few fine and medium stones; strong reaction to 10% HCl; abrupt irregular boundary.

Horizon	Soil Description
3Ckg	152 – 180 cm; light olive brown (2.5Y 5/4) loam; massive; friable; few fine light brownish gray (2.5Y 6/2) Fe depletions; few fine dark yellowish brown (10YR 4/6) and strong brown (7.5YR 4/6) mottles; common fine Mn concretions; few fine and medium stones; few $CaCO_3$ streaks; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
3Cg4	180 – 203 cm; light olive brown (2.5Y 5/4) loam; massive; friable; common medium and coarse light brownish gray (2.5Y 6/2) Fe depletions; common fine dark yellowish brown (10YR 4/6) mottles; few fine strong brown (7.5YR 4/6) mottles; common Mn concretions; few strong brown (7.5YR 4/6) concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 2 on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolomite %	Rat.	pH
A1	0 – 20	47.0	15.6	14.7	22.7	1.60	-	-	1.60	-	-	-	6.1
A2	20 – 36	46.0	12.2	15.7	26.2	0.73	-	-	0.73	-	-	-	6.7
Bw	36 – 48	47.0	15.1	15.9	22.0	0.57	3.2	0.38	0.19	0.3	2.7	0.11	7.1
Bk	48 – 61	45.8	17.1	20.0	17.1	3.08	25.7	3.08	-	1.9	12.7	0.15	8.2
2Cg	61 – 71	60.2	18.6	12.9	8.3	1.06	8.8	1.06	-	0.3	7.9	0.04	8.2
3Cg1	71 – 99	50.0	16.6	18.5	14.9	2.68	22.3	2.68	-	6.8	14.3	0.48	8.3
3Ckg	99 – 122	47.9	16.1	20.7	15.3	5.03	41.9	5.03	-	9.9	29.5	0.34	8.3
3Cg2	122 – 135	48.8	16.7	17.9	16.6	2.55	21.3	2.55	-	1.3	18.3	0.07	8.2
3Cg3	135 – 152	47.2	17.9	18.5	16.4	1.94	16.1	1.94	-	3.6	11.5	0.31	8.2
3Ckg	152 – 180	48.8	17.1	18.1	16.0	2.63	21.9	2.63	-	5.9	14.8	0.40	8.4
3Cg4	180 – 203	48.3	17.4	18.5	15.8	2.11	17.6	2.11	-	5.2	11.5	0.45	8.4

GPS Coordinates:

42.01.1792N 94.01.0996W

Soil descriptions for well 3 on transect 3

Delft loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (7.5YR 2/0) loam; weak fine subangular blocky structure; friable; many fine and medium roots; 5% fine gravel; moderately acid; gradual smooth boundary.
A2	23 – 48 cm; black (7.5YR 2/0) loam; weak fine subangular blocky structure; friable; many fine roots; few fine stones; 5% fine gravel; slightly acid; gradual smooth boundary.
A3	48 – 61 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; few fine very dark grayish brown (10YR 3/2) mottles; 2% fine gravel; many fine roots; very few fine stones; slightly acid; clear smooth boundary.
A4	61 – 81 cm; very dark gray (2.5Y 3/1) loam; moderate fine subangular blocky structure; friable; few fine very dark grayish brown (2.5Y 3/2) mottles; common fine roots; 2% fine gravel; few fine stones; neutral; clear smooth boundary.
Bg	81 – 97 cm; very dark gray (2.5Y 3/1) loam; moderate medium subangular blocky structure; friable; common fine very dark grayish brown (2.5Y 3/2) mottles; few fine olive brown (2.5Y 4/4) mottles; very few fine dark yellowish brown (10YR 4/6) mottles; common fine roots; 2% fine gravel; few fine to coarse stones; neutral; abrupt smooth boundary.
2Cg	97 – 122 cm; dark grayish brown (2.5Y 4/2) sandy loam; massive; friable; few fine very dark gray (10YR 3/1) coatings on ped faces; few fine dark yellowish brown (10YR 4/6) mottles; few fine strong brown (7.5YR 4/6) and dark brown (7.5YR ¾) concretions; few fine olive brown (2.5Y 4/4) mottles; common fine stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Ckg1	122 – 142 cm; light brownish gray (2.5Y 6/2) sandy loam/loam; massive; friable; few fine light olive brown (2.5Y 5/6) mottles; few fine olive brown (2.5Y 4/4) mottles; common Mn concretions; few fine dark yellowish brown (10YR 4/6) mottles; few fine and medium stones; many $CaCO_3$ masses and streaks; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Ckg2	142 – 178 cm; grayish brown (2.5Y 5/2) loam; massive; friable; few fine strong brown (7.5YR 5/8) mottles; common fine light olive brown (2.5Y 5/4) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few fine $CaCO_3$ streaks; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg	178 – 244 cm; light olive brown (2.5Y 5/4) loam/sandy loam; massive; friable; few medium light brownish gray (2.5Y 6/2) Fe depletions; few fine strong brown (7.5YR 5/8) mottles and concretions; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 3 on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 23	36.0	22.6	19.7	21.6	2.89	-	-	2.89	-	-	-	5.9
A2	23 – 48	31.3	19.3	23.3	26.1	2.49	-	-	2.49	-	-	-	6.4
A3	48 – 61	31.6	19.0	22.2	27.2	1.71	-	-	1.71	-	-	-	6.4
A4	61 – 81	37.5	16.6	21.5	24.5	1.18	-	-	1.18	-	-	-	6.6
Bg	81 – 97	40.7	17.4	18.7	23.2	2.01	12.1	1.45	0.56	0.3	10.8	0.03	7.2
2Cg	97 – 122	56.1	12.9	13.9	17.1	2.34	19.5	2.34	-	1.7	16.5	0.10	7.9
2Ckg1	122 – 142	53.7	14.7	15.9	15.7	2.31	19.3	2.31	-	6.5	11.8	0.55	8.3
2Ckg2	142 – 178	51.3	16.2	16.8	15.7	2.78	23.1	2.78	-	7.2	14.7	0.49	8.4
2Cg	178 – 244	53.6	10.8	17.7	17.9	2.29	19.1	2.29	-	4.9	13.1	0.37	8.4

GPS Coordinates:

42.01.1929N 94.01.0840W

Soil descriptions for well 4 on transect 3

Canisteo clay loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 25 cm; black (2.5Y 2/0) clay loam; moderate medium subangular blocky structure; friable; common fine roots; 2-5% fine gravel; few fine stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
A2	25 – 56 cm; black (2.5Y 2/0) clay loam; weak fine prismatic structure; friable; few fine very dark gray (10YR 3/1) mottles; few fine roots; 2-5% fine gravel; few fine stones; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Bg	56 – 81 cm; very dark gray (N 3/0) clay loam; weak fine prismatic structure; friable; very few fine roots; 2-5% fine gravel; few fine stones; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bkg	81 – 99 cm; very dark gray (5Y 3/1) and light olive gray (5Y 6/2) loam; moderate medium subangular blocky structure; very few fine roots; few fine stones; common $CaCO_3$ threads; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg	99 – 109 cm; light olive gray (5Y 6/2) and gray (5Y 6/1) loam; massive; friable; few fine very dark gray (5Y 3/1) mottles; few fine stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg	109 – 132 cm; very dark gray (5Y 3/1) and gray (5Y 6/1) sandy loam; massive; friable; few fine yellowish brown (10YR 5/8) mottles; few Mn concretions; common fine and coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
4Cg	132 – 160 cm; dark gray (5Y 4/1) and gray (5Y 5/1) sandy loam; massive; friable; many fine yellowish brown (10YR 5/8) mottles; few Mn concretions; few fine olive brown (2.5Y 4/4) mottles; few black (N 2/0) organic masses; common fine and medium stones; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
5Cg	160 – 183 cm; dark gray (5Y 4/1) sandy loam; massive; friable; common fine light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) mottles; few fine yellowish brown (10YR 5/8) mottles; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline; clears smooth boundary.
6Cg	183 – 216 cm; dark gray (5Y 4/1) loam; massive; friable; many fine to medium olive brown (2.5Y 4/4) mottles; few fine to coarse stones; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 4 on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 25	30.8	16.0	22.7	30.4	4.09	12.2	1.46	2.63	3.5	8.0	0.44	7.9
A2	25 – 56	26.1	22.1	20.8	31.0	3.86	17.8	2.14	1.72	1.2	15.3	0.08	7.9
Bg	56 – 81	31.9	15.4	23.1	29.6	1.06	3.6	0.43	0.63	0.0	3.3	0.03	7.9
Bkg	81 – 99	37.3	19.7	20.0	22.9	2.05	17.1	2.05	-	2.6	13.4	0.19	8.3
2Cg	99 – 109	48.6	22.4	14.0	15.1	1.89	15.7	1.89	-	2.9	11.8	0.25	8.4
3Cg	109 – 132	58.9	12.6	13.2	15.3	3.14	26.2	3.14	-	4.1	20.4	0.20	8.3
4Cg	132 – 160	65.1	12.4	9.6	12.8	2.66	22.2	2.66	-	3.1	17.6	0.18	8.3
5Cg	160 – 183	56.8	12.7	14.8	15.7	2.31	19.2	2.31	-	4.3	13.7	0.31	8.3
6Cg	183 – 218	51.8	12.0	18.3	18.0	2.30	19.2	2.30	-	3.9	14.1	0.28	8.3

GPS Coordinates:

42.01.2031N   94.01.0674W

Soil descriptions for well 5 on transect 3

Canisteo clay loam   Three-way Sedge Wetland Zone   Footslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; common medium roots; many fine roots; 2% fine gravel; slightly alkaline; gradual smooth boundary.
A2	23 – 43 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; common fine roots; few medium roots; 2% fine gravel; few fine stones; slightly alkaline; clear smooth boundary.
A3	43 – 61 cm; black (N 2/0) clay loam; moderate medium subangular blocky structure; friable; few fine olive gray (5Y 5/2) mottles; few fine roots; few fine stones; 2% fine gravel; slightly alkaline; clear smooth boundary.
Bg1	61 – 74 cm; very dark gray (N 3/0) clay loam; moderate fine subangular blocky structure; friable; very few fine olive gray (5Y 5/2) mottles; few fine roots; few fine stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg2	74 – 86 cm; very dark gray (N 3/0) clay loam; moderate fine subangular blocky structure; friable; very few fine olive gray (5Y 5/2) mottles; very few fine roots; 2% fine gravel; few fine stones; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
2Cg1	86 – 122 cm; olive gray (5Y 5/2) and dark gray (5Y 4/1) sandy loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; few fine stones; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Cg2	122 – 150 cm; olive gray (5Y 5/2) and dark gray (5Y 4/1) sandy loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; few fine and medium Mn concretions; few fine dark brown (7.5YR ¾) Fe nodules; few fine stones; 5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
3Cg	150 – 208 cm; dark gray (5Y 4/1) and gray (5Y 5/1) loam; massive; friable; few fine olive brown (2.5Y 4/4) mottles; few medium and coarse dark yellowish brown (10YR 4/6) mottles; sand lenses between peds; few fine Mn concretions; few fine and medium stones; slight reaction to 10% HCl; slightly alkaline.

Characterization data for well 5 on transect 3 in Harrier's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolo.	Ratio	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 23	29.1	17.1	23.7	30.0	4.13	4.3	0.52	3.61	0.7	3.3	0.21	7.4
A2	23 – 43	29.1	15.5	24.5	30.9	2.17	4.6	0.56	1.61	1.8	2.6	0.08	7.4
A3	43 – 61	31.9	13.3	23.5	31.3	1.40	2.0	0.24	1.16	0.1	1.8	0.06	7.4
Bg1	61 – 74	30.9	13.1	24.1	32.0	3.91	22.8	2.74	1.17	1.3	19.8	0.07	7.6
Bg2	74 – 86	34.0	11.7	23.5	30.7	2.23	12.4	1.49	0.74	0.3	11.1	0.03	7.6
2Cg1	86 – 122	67.7	7.0	9.5	15.9	1.71	14.2	1.71	-	1.2	12.0	0.10	7.6
2Cg2	122 – 150	72.6	6.1	7.3	14.0	1.47	12.2	1.47	-	0.3	10.9	0.03	7.9
3Cg	150 – 208	41.4	17.5	21.3	19.8	3.19	26.5	3.19	-	1.8	22.8	0.08	7.9

GPS Coordinates:

42.01.2041N   94.01.0586W

Soil descriptions for well 6 on transect 3

Okoboji silty clay loam Pond Depression Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) silty clay loam; weak fine granular structure; friable; many fine roots; common fine dark grayish brown (2.5Y 4/2) mottles; many roots sheaths; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A2	15 – 28 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; common fine olive brown (2.5Y 4/4) pore linings; common fine very dark grayish brown (2.5Y 3/2) mottles; many fine roots; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	28 – 48 cm; black (2.5Y 2/1) and very dark gray (N 3/0) silty clay loam; moderate medium subangular blocky structure; friable; common fine roots; 2% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A4	48 – 66 cm; black (2.5Y 2/0) silty clay loam; moderate medium subangular blocky structure; friable; common fine olive gray (5Y 5/2) mottles; few fine roots; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg1	66 – 79 cm; gray (5Y 5/1) silty clay loam; moderate fine prismatic structure; friable; few very dark gray (N 3/0) krotovinas; few fine dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) mottles; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg2	79 – 104 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) silty clay loam; weak fine prismatic structure; friable; few fine olive brown (2.5Y 4/4) and dark brown (7.5YR 3/3) mottles; very few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg	104 – 142 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) silty clay loam; massive; friable; few fine dark brown (7.5YR 3/3) and olive brown (2.5Y 4/4) mottles; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Ckg	142 – 170 cm; gray (5Y 5/1 and 6/1) loam; massive; friable; common fine dark yellowish brown (10YR 4/6) mottles; few fine $CaCO_3$ threads; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
3Cg	170 – 211 cm; gray (5Y 5/1) and dark gray (5Y 4/1) loam; massive; friable; common fine to coarse olive brown (2.5Y 4/4) mottles; few fine and medium stones; 2% fine gravel; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 6 on transect 3 in Harrier's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OC	Calcite	Dolo.	Ratio	pH
	cm	%	%	%	%	%	%	%	%	%	%		
A1	0 – 15	10.3	20.1	35.3	34.3	7.48	22.9	2.75	4.73	0.6	20.5	0.03	7.5
A2	15 – 28	14.7	18.1	32.7	34.6	4.98	16.1	1.94	3.04	1.1	13.9	0.08	7.5
A3	28 – 48	11.1	17.4	35.2	36.3	1.32	2.9	0.35	0.97	0.3	2.4	0.13	7.6
A4	48 – 66	11.5	19.2	34.9	34.4	1.22	4.7	0.56	0.66	0.9	3.5	0.26	7.7
Bg1	66 – 79	6.6	21.6	39.1	32.7	1.28	9.6	1.15	0.13	0.2	8.6	0.020.	7.8
Bg2	79 – 104	9.5	17.1	41.2	32.2	2.18	18.2	2.18	-	2.8	14.2	20	8.0
Cg	104 – 142	7.4	17.1	43.6	31.9	2.58	21.5	2.58	-	4.5	15.6	0.29	8.1
2Ckg	142 – 170	32.1	11.5	30.4	26.0	3.02	25.2	3.02	-	7.7	16.1	0.48	8.2
3Cg	170 – 211	44.9	14.0	22.9	18.1	2.50	20.8	2.50	-	3.8	15.7	0.24	8.2

GPS Coordinates:

42.01.2085N 94.01.0518W

Soil descriptions of Well 7 on transect 3

Okoboji silty clay loam Pond Depression Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 10 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; very few fine very dark grayish brown (2.5Y 3/2) mottles; many fine roots; moderately acid; clear wavy boundary.
A2	10 – 25 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; common fine very dark grayish brown (2.5Y 3/2) mottles; olive brown (2.5Y 4/4) pore linings and mottles; many fine roots; moderately acid; abrupt smooth boundary.
A3	25 – 41 cm; black (N 2/0) silty clay loam; weak medium subangular blocky structure; friable; common very dark grayish brown (2.5Y 3/2) pore linings and mottles; common fine roots; slightly acid; clear smooth boundary.
A4	41 – 61 cm; black (2.5Y 2/0) and very dark gray (N 3/0) silty clay loam; weak fine prismatic structure; friable; few fine roots; neutral; clear smooth boundary.
Bg1	61 – 91 cm; very dark gray (N 3/0) silty clay loam; moderate fine prismatic structure; friable; common fine very dark grayish brown (2.5Y 3/2) and very dark brown (2.5Y 2/2) pore linings; few fine roots; few roots sheaths; neutral; gradual smooth boundary.
Bg2	91 – 119 cm; very dark gray (N 3/0) silty clay loam; moderate fine prismatic structure; friable; few fine grayish brown (2.5Y 5/2) mottles; neutral; abrupt smooth boundary.
Ckg	119 – 140 cm; light olive gray (5Y 6/2) and gray (5Y 5/1 and 6/1) silty clay loam; massive; friable; few fine dark yellowish brown (10YR 4/6) mottles; common fine dark yellowish brown (10YR ¾) mottles; common fine $CaCO_3$ streaks; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg	140 – 188 cm; gray (5Y 5/1) silty clay loam; massive; friable; common fine dark yellowish brown (10YR ¾) mottles; few fine dark yellowish brown (10YR 4/6) mottles; few Mn concretions; strong reaction to 10% HCl; slightly alkaline.

Characterization data for well 7 on transect 3 in Harrier's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OC %	Calcite %	Dolo. %	Ratio	pH
A1	0 – 10	6.5	14.8	41.4	37.3	5.52	-	-	5.52	-	-	-	6.0
A2	10 – 25	8.6	15.9	39.4	36.1	5.17	-	-	5.17	-	-	-	6.0
A3	25 – 41	10.4	18.5	38.0	33.1	4.05	-	-	4.05	-	-	-	6.3
A4	41 – 61	5.3	15.0	40.0	39.7	1.77	17.2	2.06	1.77	0.4	15.5	0.03	7.1
Bg1	61 – 91	3.3	15.4	41.7	39.6	-	12.1	1.45	-	0.8	10.4	0.08	7.0
Bg2	91 – 119	2.4	16.3	48.3	33.0	-	20.1	2.41	-	0.5	18.0	0.03	7.3
Ckg	119 – 140	4.1	17.2	51.5	27.2	4.39	36.6	4.39	-	27.3	8.5	3.21	8.1
Cg	140 – 188	4.7	18.8	48.2	28.3	3.27	27.2	3.27	-	10.2	15.7	0.65	8.1

GPS Coordinates:

42.01.2280N 94.00.9688W

APPENDIX C. SOIL DESCRIPTIONS AND CHARACTERIZATION DATA FOR WELLS IN GORDON'S MARSH COMPLEX

Soil descriptions for well 1 on transect 1

Nicollet clay loam Upland Prairie Summit Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 - 15 cm; black (2.5Y 2/1) clay loam; weak fine subangular blocky structure; friable; few medium roots; common fine roots; 5-7% fine gravel; moderately acid; clear smooth boundary.
A2	15 - 28 cm; black (2.5Y 2/1) clay loam; few fine distinct spherical dark grayish brown (2.5Y 4/2) masses; moderate fine subangular block structure; friable; few medium roots; common fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
Bw1	28 - 61cm; dark grayish brown (2.5Y 4/2) clay loam; common coarse distinct black (5Y 2/1) organic matter coatings on ped faces; moderate medium subangular structure; slightly firm; few medium and fine roots; 3-5% fine gravel; slightly acid; clear smooth boundary.
Bw2	61 – 76 cm; dark grayish brown (2.5Y 4/2) clay loam; few fine distinct black (5Y 2/1) organic matter coatings on ped faces; moderate medium subangular structure; firm; few medium and fine roots; 3% fine gravel; slightly acid; clear smooth boundary.
Bg	76 – 99 cm; olive brown (2.5Y 4/4) loam; few fine prominent yellowish brown (10YR 5/8) irregular mottles; very few fine distinct black (5Y 2/1) spherical organic matter coatings on ped faces; moderate coarse subangular blocky structure; firm; few fine and medium roots; 1% fine gravel; few medium stones; neutral; clear smooth boundary.
Ckg	99 – 109 cm; olive brown (2.5Y 4/4) loam; few fine prominent irregular yellowish brown (10YR 5/8) concentrations; very few medium distinct black (5Y 2/1) organic matter coatings on ped faces; few coarse $CaCO_3$ nodules; moderate fine prismatic structure; firm; few fine roots; <1% fine gravel; few medium and coarse stones; strong effervescence with 10% HCl; slightly alkaline; clear smooth boundary.
Ckg2	109 – 124 cm; olive brown (2.5Y 4/4) loam; few very fine distinct dark gray (5Y 4/1) Fe depletions; few large organic matter krotovinas; very few medium distinct black (5Y 2/1) organic matter coatings on ped faces; many fine $CaCO_3$ threads; massive; firm; few fine roots; few medium stones; strong effervescence with 10% HCl; moderately alkaline; clear smooth boundary.
Ckg3	124 – 135 cm; olive brown (2.5Y 4/4) and dark gray (5Y 4/1) loam; few fine prominent irregular yellowish brown (10YR 5/8) mottles; few medium $CaCO_3$ concretions; common fine spherical Mn concretions; massive; friable; strong effervescence with 10% HCl; moderately alkaline; abrupt smooth boundary.
Ckg4	135 – 147 cm; olive brown (2.5Y 4/4) loam; few medium distinct dark gray (5Y 4/1) irregular Fe depletions; few fine prominent irregular yellowish brown (10YR 5/8) concretions; few medium $CaCO_3$ concretions; massive; friable; strong effervescence with 10% HCl; common medium stones; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
2Ckg	147 – 155 cm; dark gray (5Y 4/1) silt loam; common medium distinct irregular yellowish brown (10YR 5/8) Fe mottles; few medium and coarse $CaCO_3$ concretions; many very fine Mn concretions; few coarse Mn nodules with strong brown (7.5 YR 4/6) coatings around nodule; massive; friable; strong effervescence with 10% HCl; moderately alkaline; abrupt smooth boundary.
3Cg	155 – 163 cm; olive brown (2.5Y 4/4) sandy loam; few fine distinct irregular yellowish brown (10YR 5/8) mottles; few fine Mn concretions; loose; friable; slight effervescence with 10% HCl; moderately alkaline; abrupt smooth boundary.
4Ckg	163 – 170 cm; dark gray (5Y 4/1) loam; common medium prominent yellowish brown irregular (10YR 5/8) Fe mottles; few medium and coarse $CaCO_3$ concretions; few Mn concretions; few medium stones; massive; friable; moderately alkaline; strong effervescence with 10% HCl; abrupt smooth boundary.
5Cg	170 – 188 cm; olive brown (2.5Y 4/4) sandy loam; few fine distinct irregular yellowish brown (10YR 5/8) Fe mottles; few fine Mn concretions; loose; friable; moderately alkaline; slight effervescence with 10% HCl; abrupt smooth boundary.
6Ckg	188 – 201 cm; olive brown (2.5Y 4/4) and dark gray (5Y 4/1) loam; few fine prominent yellowish brown (10YR 5/8) Fe mottles; few medium $CaCO_3$ concretions; few fine Mn concretions; sand lenses between peds; massive; friable; moderately alkaline; strong effervescence with 10% HCl; clear smooth boundary.
7Ckg	201 – 221 cm; dark gray (5Y 4/1) sandy loam; few medium prominent yellowish brown irregular (10YR 5/8) Fe mottles; few medium $CaCO_3$ concretions; massive; friable; moderately alkaline; strong effervescence with 10% HCl; clear smooth boundary.
8Ckg	221+ cm; dark gray (5Y 4/1) loam; few medium prominent yellowish brown irregular (10YR 5/8) Fe mottles; few medium $CaCO_3$ concretions; massive; friable; moderately alkaline; strong effervescence with 10% HCl; clear smooth boundary.

Characterization data for well 1 on transect 1 in Gordon Marsh.

Horizon	Depth cm	Sand %	Fine Silt %	Coarse Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0-15	32.1	17.2	21.7	29.0	2.69	-	-	4.63	5.8	-	-	-
A2	15-28	31.2	17.2	20.9	30.7	2.34	-	-	4.02	5.9	-	-	-
Bw1	28-61	32.7	16.1	20.5	30.7	1.84	-	-	3.16	6.2	-	-	-
Bw2	61-76	38.3	13.4	18.9	29.4	1.06	-	-	1.82	6.5	-	-	-
Bg	76-99	45.4	12.2	18.2	24.2	0.45	2.0	0.24	0.36	7.1	0.1	1.8	0.06
Ckg1	99-109	36.0	18.2	26.5	19.3	-	16.5	1.98	-	7.8	6.1	9.6	0.64
Ckg2	109-124	36.5	15.7	24.5	23.3	-	12.6	1.51	-	7.9	3.3	8.6	0.38
Ckg3	124-135	38.4	17.4	24.1	20.2	-	19.0	2.28	-	8.1	6.9	11.1	0.62
Ckg4	135-147	46.1	14.2	21.5	18.3	-	16.8	2.02	-	8.3	6.1	9.9	0.62
2Ckg	147-155	22.5	19.3	36.5	21.7	-	20.2	2.43	-	8.2	8.8	10.5	0.84
3Cg	155-163	67.0	11.1	12.1	9.8	-	13.7	1.64	-	8.2	3.7	9.2	0.40
4Ckg	163-170	41.3	17.9	22.5	18.3	-	17.5	2.09	-	8.2	5.8	10.7	0.54
5Cg	170-188	61.7	12.1	14.2	11.9	-	14.8	1.78	-	8.3	3.9	10.1	0.39
6Ckg	188-201	48.6	17.0	21.0	13.4	-	17.6	2.11	-	8.3	6.7	10.0	0.67
7Ckg	201-221	56.2	14.0	16.3	13.5	-	18.5	2.22	-	8.4	5.2	12.3	0.42
8Ckg	221+	49.1	15.7	20.7	14.5	-	17.8	2.13	-	8.3	6.4	10.5	0.61

GPS Coordinates:

42.36.6938N 93.52.8164W

Soil descriptions for well 2 on transect 1

Nicollet clay loam Upland Prairie Shoulder Slope Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 20 cm; black (5Y 2/1) clay loam; weak fine subangular blocky structure; friable; many medium and fine roots; 5-10% fine gravel; moderately acid; clear smooth boundary.
A2	20 – 41 cm; black (5Y 2/1) clay loam; few fine distinct spherical dark grayish brown (2.5Y 4/2) mottles; moderate fine subangular block structure; friable; many fine roots; common medium roots; 5% fine gravel; moderately acid; clear smooth boundary.
Bw	41 – 61 cm; dark grayish brown (2.5Y 4/2) clay loam; few fine distinct spherical (5Y 2/1) organic coatings on ped faces; moderate medium subangular blocky structure; friable; many fine roots; few medium stones; 3% fine gravel; slightly acid; gradual smooth boundary.
Bg1	61 – 79 cm; dark grayish brown (2.5Y 4/2) silty clay loam; few fine faint irregular olive brown (2.5Y 4/4) mottles; few fine black (5Y 2/1) organic coatings on ped faces; moderate coarse subangular blocky structure; firm; common fine roots; neutral; clear smooth boundary.
Bg2	79 – 97 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silty clay loam; few very fine distinct black (5Y 2/1) organic coatings on ped faces; very few fine prominent irregular yellowish brown (10YR 5/8) Fe mottles; very few fine distinct spherical olive brown (2.5Y 4/4) Fe mottles; moderate fine prismatic structure; firm; few fine roots; neutral; clear smooth boundary.
BCg	97 – 107 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silt loam; very few fine distinct spherical olive brown (2.5Y 4/4) Fe mottles; common fine prominent irregular yellowish brown (10YR 5/8) Fe mottles; few fine distinct black (5Y 2/1) organic cutans; moderate fine prismatic structure; firm; few fine roots; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg	107 – 122 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silt loam; many medium prominent irregular yellowish brown (10YR 5/8) Fe mottles; many fine $CaCO_3$ threads; few fine Mn concretions; massive; friable; strong effervescence with HCl; moderately alkaline; clear smooth boundary.
2Ckg	122 – 137 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silt loam; few fine and medium prominent irregular yellowish brown (10YR 5/8) Fe mottles; very few fine strong brown (7.5YR 4/6) Fe mottles; few medium CaCO3 concretions; few fine Mn concretions; massive; friable; strong effervescence with HCl; 2% fine gravel; moderately alkaline; clear smooth boundary.
2Cg1	137 – 173 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silt loam; many medium prominent irregular yellowish brown (10YR 5/8) Fe mottles; many fine sand grains between peds; many very fine Mn concretions between peds; massive; friable; strong effervescence with HCl; strongly alkaline; abrupt smooth boundary.

Horizon	Soil Description
2Cg2	173 – 201 cm; grayish brown (2.5Y 5/2) silt loam; many medium distinct yellowish brown (10YR 5/8) Fe mottles; many fine sand grains between peds; common very fine Mn concretions between peds; few medium $CaCO_3$ threads; massive; friable; strong effervescence with HCl; strongly alkaline; gradual smooth boundary.
2Cg3	201 – 221 cm; grayish brown (2.5Y 5/2) silt loam; few medium distinct irregular dark gray (5Y 4/1) and light olive gray (5Y 6/2) Fe depletions; few medium distinct irregular yellowish brown (10YR 5/8) Fe mottles; strong brown (7.5YR 4/6) cylindrical pore lining; few sand grains between peds; few fine Mn concretions; massive; friable; moderately alkaline; strong effervescence with HCl; clear smooth boundary.
3Cg	221+ cm; dark gray (5Y 4/1) silt clay loam; few coarse prominent irregular yellowish brown (10YR 5/4 and 5/8) Fe mottles; massive; friable; moderately alkaline; strong effervescence with HCl.

Characterization data for well 2 on transect 1 in Gordon's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OM	pH	Calcite	Dolo.	Ratio
A1	0 – 20	28.3	19.2	23.3	29.2	2.85	-	-	4.90	5.6	-	-	-
A2	20 – 41	19.1	19.8	27.9	33.2	2.05	-	-	3.53	5.7	-	-	-
Bw	41 – 61	20.8	20.4	26.6	32.2	1.04	-	-	1.79	6.5	-	-	-
Bg1	61 – 79	18.1	19.8	30.4	31.8	0.61	-	-	1.05	6.7	-	-	-
Bg2	79 – 97	16.7	25.5	28.5	29.4	0.42	1.8	0.21	0.36	7.0	0.1	1.6	0.06
BCg	97 – 107	19.5	22.1	34.3	24.1	0.51	4.0	0.49	-	7.5	0.9	2.9	0.31
Ckg	107 – 122	8.3	18.6	52.7	20.4	-	18.9	2.27	-	8.0	4.7	13.1	0.36
2Ckg	122 – 137	24.2	25.0	33.5	17.2	-	17.8	2.14	-	8.2	5.9	11.0	0.54
2Cg1	137 – 173	24.1	26.5	33.6	15.8	-	20.1	2.41	-	8.5	5.1	13.8	0.37
2Cg2	173 – 201	18.2	29.4	36.8	15.6	-	20.6	2.47	-	8.5	5.1	14.2	0.36
2Cg3	201 – 221	11.9	27.5	43.6	17.0	-	19.9	2.39	-	8.4	3.3	15.3	0.22
3Cg	221+	7.0	19.1	43.8	30.1	-	17.8	2.15	-	8.3	5.0	11.9	0.42

GPS Coordinates:

42.23.7017N 93.52.8320W

Soil descriptions for well 3 on transect 1

Webster clay loam Upland Prairie Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 20 cm; black (2.5Y 2/0) clay loam; moderate fine subangular blocky structure; friable; few fine to medium roots; 3-5% fine gravel; slightly acid; clear smooth boundary.
A2	20 – 38 cm; black (2.5Y 2/0) clay loam; weak medium subangular blocky structure; friable; few fine to medium roots; 3-5% fine gravel; neutral; clear smooth boundary.
A3	38 – 53 cm; black (2.5Y 2/0) clay loam; few fine prominent olive gray (5Y 5/2) Fe depletions; moderate medium subangular blocky structure; friable; few tubular shaped pores and channels; few fine roots; 3-5% fine gravel; neutral; gradual smooth boundary.
Bg	53 – 74 cm; dark gray (5Y 4/1) clay loam; prominent black (2.5Y 2/0) coatings on ped faces; weak fine prismatic parting to moderate medium subangular blocky structure; firm; few fine roots; 2-3% fine gravel; neutral; clear smooth boundary.
Bkg	74 – 86 cm; light olive gray (5Y 6/2) loam/clay loam; faint olive gray (5Y 4/1) coatings on ped faces; very few fine prominent yellowish brown (10YR 5/8) mottles; prominent black (2.5Y 2/0) coatings and krotovinas; friable; few fine roots; few medium and coarse $CaCO_3$ concretions; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg1	86 – 102 cm; light olive gray (5Y 6/2) loam; few fine prominent yellowish brown (10YR 5/8) mottles; prominent black (2.5Y 2/0) coatings and krotivinas; weak medium subangular blocky structure; friable; few medium and coarse $CaCO_3$ concretions; few $CaCO_3$ streaks; few coarse stones; few fine roots; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg2	102 – 124 cm; light olive gray (5Y 6/2) and gray (5Y 5/1) loam; common fine prominent yellowish brown (10YR 5/4 and 5/8) mottles; massive; friable; common medium and fine Mn concretions; few coarse and medium stones; common very fine round $CaCO_3$ concretions; <3% fine gravel; slight reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg1	124 – 152 cm; light olive gray (5Y 6/2) and gray (5Y 5/1) loam; many fine to coarse prominent yellowish brown (10YR 5/4 and 5/8) mottles; few prominent dark brown (7.5YR 3/5) pore linings; massive; friable; few coarse to fine stones; few fine Mn concretions; slight reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	152 – 165 cm; gray (5Y 5/1) loam; many fine to coarse prominent yellowish brown (10YR 5/4 and 5/8) and dark brown (7.5YR 3/4) mottles; massive; friable; few Mn concretions between peds; root sheaths; slight reaction to HCl; moderately alkaline; clear wavy boundary.
2Cg	165 – 198 cm; yellowish brown (10YR 5/8) and dark brown (7.5YR 3/4) sandy loam; loose; friable; few coarse to medium stones; slight reaction to 10% HCl; moderately alkaline.

Characterization data for well 3 on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0 – 20	27.5	18.9	24.6	29.0	3.38	-	-	5.81	6.3	-	-	-
A2	20 – 38	23.7	18.7	25.6	32.0	2.68	-	-	4.61	6.6	-	-	-
A3	38 – 53	22.7	16.0	26.0	35.3	1.28	-	-	2.20	6.9	-	-	-
Bg	53 – 74	23.6	15.7	27.6	33.2	0.67	2.4	0.29	0.65	7.3	0.7	1.6	0.44
Bkg	74 – 86	35.2	15.2	22.3	27.3	1.51	11.3	1.36	0.26	7.8	0.4	10.1	0.04
Ckg1	86 – 102	42.1	13.6	23.2	21.2	2.13	17.0	2.04	0.15	8.1	5.7	10.4	0.55
Ckg2	102 – 124	40.3	14.2	25.1	20.3	-	18.1	2.17	-	8.4	4.7	12.3	0.38
Cg1	124 – 152	44.1	17.9	18.9	19.1	-	18.3	2.19	-	8.4	6.3	11.0	0.57
Cg2	152 – 165	35.8	18.5	25.2	20.6	-	17.7	2.12	-	8.2	3.6	13.0	0.28
2Cg	165 – 198	75.4	5.7	9.5	9.4	-	18.5	2.22	-	8.3	6.8	10.8	0.63

GPS Coordinates:

42.23.7295N 93.52.8545W

Soil descriptions for well 4 on transect 1

Delft clay loam Upland Prairie Backslope Position
Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 20 cm; black (2.5Y 2/0) clay loam; weak fine subangular blocky structure; friable; common medium and many fine roots; 3-5% fine gravel; neutral; clear smooth boundary.
A2	20 – 36 cm; black (2.5Y 2/0) silty clay loam; few fine faint very dark grayish brown (2.5Y 3/2) accumulations; weak medium subangular blocky structure; friable; few medium and common fine roots; 3-5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
A3	36 – 61 cm; very dark gray (2.5Y 3/0) silty clay loam; few fine faint very dark grayish brown (2.5Y 3/2) accumulations; moderate medium subangular blocky structure; friable; few fine roots; 3-5% fine gravel; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
AB	61 – 79 cm; very dark gray (5Y 3/1) silty clay loam; few fine distinct very dark grayish brown (2.5Y 3/2) mottles; moderate medium subangular blocky structure; firm; few fine roots; few fine pebbles; slight reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Bg1	79 – 86 cm; dark gray (5Y 4/1) and gray (5Y 5/1) silty clay loam; few fine distinct/prominent very dark grayish brown (2.5Y 3/2) accumulations; moderate medium subangular blocky structure; firm; very few fine roots; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Bg2	86 – 107 cm; olive gray (5Y 5/2) silty clay loam; few fine distinct dark gray (5Y 4/1) coating on ped faces; few fine prominent yellowish brown (10YR 5/8) mottles; distinct black (2.5Y 2.0) coatings along root channels; moderate coarse subangular blocky structure; slightly firm; slight reaction to HCl; very few fine roots; very few very fine stones; moderately alkaline; clear smooth boundary.
2Ckg	107 – 130 cm; light olive gray (5Y 6/2) and gray (5Y 5/1) loam/sandy loam; few fine prominent yellowish brown (10YR 5/8) mottles; massive; friable; common fine to medium $CaCO_3$ masses; few fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg	130 – 140 cm; light olive gray (5Y 6/2) and gray (5Y 5/1) loamy sand; common fine prominent yellowish brown (10YR 5/4 and 5/8) mottles; loose; friable; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary
4Cg1	140 – 155 cm; gray (5Y 5/1) sandy loam; few fine prominent dark brown (7.5YR 3/4) mottles; massive; slightly firm; few Mn concretions; few coarse stones; strong reaction to 10%HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
4Cg2	155 – 175 cm; olive brown (2.5Y 4/4) and gray (5Y 5/1) sandy loam/loam; few fine prominent yellowish brown (10YR 5/4 and 5/8) mottles; massive; slightly firm; few medium stones; few Mn concretions; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
4Cg3	175 – 206 cm; olive gray (5Y 5/2) and gray (5Y 5/1) sandy loam; few fine prominent yellowish brown (10YR 5/4 and 5/8) mottles; massive; firm; few stones; few medium Mn concretions and nodules; moderately alkaline; strong reaction to 10% HCl.

Characterization data for well 4 on transect 1 in Gordon's Marsh.

Horizon	Depth	Sand	Coa. Silt	Fine Silt	Clay	TC	CCE	IC	OM	pH	Calcite	Dolomite	Ratio
	cm	%	%	%	%	%	%	%	%		%	%	
A1	0 – 20	21.4	21.9	25.3	31.4	4.13	2.7	0.32	6.55	7.3	0.5	2.0	0.25
A2	20 – 36	14.8	23.5	28.6	33.0	4.37	3.3	0.40	6.83	7.5	1.2	2.0	0.60
A3	36 – 61	14.7	21.1	30.1	34.2	2.66	2.0	0.24	4.16	7.6	0.1	1.8	0.06
AB	61 – 79	13.0	21.0	30.2	35.8	1.69	2.4	0.29	2.41	7.6	0.7	1.6	0.44
Bg1	79 – 86	15.8	20.5	30.0	33.6	1.14	3.6	0.43	1.22	8.0	0.2	3.1	0.06
Bg2	86 – 107	19.2	23.4	28.0	29.4	1.54	6.9	0.83	1.22	7.9	1.0	5.4	0.19
2Ckg	107 – 130	51.9	13.8	18.0	16.3	-	14.5	1.74	-	8.2	2.5	11.0	0.23
3Cg	130 – 140	82.6	5.7	5.9	5.7	-	13.3	1.60	-	8.3	3.5	9.1	0.38
4Cg1	140 – 155	55.0	11.1	20.2	13.7	-	18.6	2.23	-	8.2	4.4	13.1	0.34
4Cg2	155 – 175	51.9	12.4	17.5	18.1	-	17.0	2.04	-	8.2	5.7	10.4	0.55
4Cg3	175 - 206	57.2	12.1	15.9	14.9	-	16.2	1.95	-	8.3	3.6	11.6	0.31

GPS Coordinates:

42.23.7441N93.52.8633W

Soil descriptions for well 5 on transect 1

Delft clay loam Wet Prairie Footslope Position
Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 25 cm; black (N2/0) clay loam; weak fine granular structure; friable; many fine roots; few tuber roots; 2-3% fine gravel; slight effervescence with 10% HCl; slightly alkaline; clear smooth boundary.
A2	25 – 51 cm; black (N2/0) and very dark gray (N3/0) silty clay loam; moderate fine subangular blocky parting to weak fine granular structure; friable; few fine roots; 2% fine gravel; slight effervescence with 10% HCl; slightly alkaline; clear smooth boundary.
A3	51 – 74 cm; very dark gray (N3/0) silty clay loam; moderate medium subangular blocky structure; slightly firm; few fine roots; 2% fine gravel; slightly alkaline; slight effervescence with 10% HCl; clear smooth boundary.
ABg	74 – 89 cm; very dark gray (N3/0) silty clay loam; few fine prominent olive brown (2.5Y 4/4) mottles; moderate medium subangular blocky structure; slightly firm; few fine roots; slight effervescence with 10% HCl; moderately alkaline; abrupt irregular boundary.
Bg	89 – 107 cm; dark gray (5Y 4/1) silt loam; very distinct dark gray (2.5Y 3/0) coatings on ped faces; many medium and coarse distinct olive brown (2.5Y 4/4) mottles; few fine prominent yellowish brown (10YR 5/8) mottles; strong coarse subangular blocky structure; slightly firm; few fine roots; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg	107 – 117 cm; gray (5Y 5/1) silt loam; few fine faint light olive gray (5Y 6/2) Fe depletions; common fine prominent yellowish brown (10YR 5/8) mottles; massive; slightly firm; very few fine roots; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
2Cg	117 – 127 cm; mottled gray (5Y 5/1), olive gray (5Y 6/2), and very dark gray (5Y 3/1) loam/sandy loam; massive; friable; few very fine $CaCO_3$ concentrations; few coarse rock fragments; common fine gravel; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
3Cg	127 – 150 cm; gray (5Y 5/1) and olive gray (5Y 6/2) sandy loam; few medium prominent yellowish brown (10YR 5/8) mottles; loose; friable; strong reaction to HCl; moderately alkaline; abrupt smooth boundary.
4Cg1	150 – 175 cm; gray (5Y 5/1) sandy loam; few medium to coarse prominent yellowish brown (10YR 5/4 and 5/8) mottles; many fine distinct olive brown (2.5Y 4/4) mottles; massive; Mn nodules mixed with quartz fragments; slightly firm; strong reaction to 10% HCl; strongly alkaline; clear smooth boundary.
4Cg2	175 – 213 cm; gray (5Y 5/1) and olive gray (5Y 5/2) sandy loam; few fine prominent yellowish brown (10YR 5/8) mottles; massive; slightly firm; few coarse stones; few medium to coarse Mn nodules mixed with quartz fragments; moderately alkaline; strong reaction to 10% HCl.

Characterization data for well 5 on transect 1 in Gordon's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OM	pH	Calcite	Dolo.	Ratio
	cm	%	%	%	%	%	%	%	%		%	%	
A1	0 – 25	18.5	22.0	27.0	32.4	5.54	3.8	0.45	8.75	7.7	1.4	2.2	0.64
A2	25 – 51	13.9	22.8	31.8	31.5	2.33	2.4	0.29	3.51	7.8	0.5	1.8	0.28
A3	51 – 74	12.3	22.7	32.2	32.8	1.49	2.5	0.29	2.06	7.8	0.3	2.0	0.15
ABg	74 – 89	14.4	22.1	32.4	31.0	1.23	4.0	0.48	1.29	8.1	0.7	3.1	0.23
Bg	89 – 107	12.3	25.7	36.8	25.2	1.32	10.1	1.22	0.17	8.1	0.1	9.4	0.01
Cg	107 – 117	31.2	29.4	22.3	17.1	-	12.6	1.52	-	8.3	0.6	11.1	0.05
2Cg	117 – 127	50.8	17.1	17.5	14.6	-	12.6	1.51	-	8.3	0.8	10.9	0.07
3Cg	127 – 150	73.4	6.6	9.9	10.2	-	16.1	1.93	-	8.5	4.6	10.6	0.43
4Cg1	150 – 175	54.7	15.7	16.8	12.9	-	17.4	2.09	-	8.3	3.8	12.5	0.30
4Cg2	175 – 213	54.8	16.2	16.1	12.9	-	18.5	2.22	-	8.2	5.8	11.6	0.50

GPS Coordinates:

42.23.7568N 93.52.8799W

Soil descriptions for well 6 on transect 1

Delft silty clay loam
Three-way sedge (*Dulichium arundinaceum*) wetland zone Footslope Position
Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; many fine roots; 3-5% fine gravel; slightly alkaline; clear smooth boundary.
A2	23 – 38 cm; black (N 2/0) silty clay loam; very few fine prominent dark yellowish brown (10YR 3/4) accumulations around roots; few prominent dark yellowish brown (10YR 4/6) pore linings; few fine distinct gray (5Y 4/1) and prominent dark grayish brown (2.5Y 4/2) depletion zones around pore linings; moderate medium to fine subangular blocky structure; friable; common fine roots; 2-3% fine gravel; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
A3	38 – 51 cm; very dark gray (N 3/0) silty clay loam; few prominent dark yellowish brown (10YR 4/6) and strong brown (7.5YR 4/6) pore linings; few fine distinct gray (5Y 4/1) and prominent dark grayish brown (2.5Y 4/2) Fe depletions; moderate medium subangular blocky structure; firm; few fine roots; 1% fine gravel; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
A4	51 – 64 cm; very dark gray (N 3/0) silt loam; common prominent strong brown (7.5YR 4/6) pore linings; few medium distinct gray (5Y 4/1) depletions; moderate coarse subangular blocky structure; firm; few fine roots; moderately alkaline; slight reaction to 10% HCl; clear smooth boundary.
Bg1	64 – 76 cm; dark gray (5Y 4/1) silty clay loam; few fine distinct dark grayish brown (2.5Y 4/2) and prominent olive brown (2.5Y 4/4) mottles; common prominent strong brown (7.5YR 4/6) pore linings; distinct very dark gray (N 3/0) krotovinas and masses on ped faces; moderate coarse subangular blocky structure; firm; few fine roots; moderately alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
Bg2	76 – 94 cm; olive brown (2.5Y 4/4) silty clay loam; few fine and medium prominent gray (5Y 4/1) Fe depletions; few medium prominent black (5Y 2/1) krotovinas; prominent strong brown (7.5YR 4/6) pore linings; weak fine prismatic structure; firm; very few fine roots; moderately alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
BCg	94 – 107 cm; dark gray (5Y 4/1) silt loam; common medium to fine prominent olive brown (2.5Y 4/4) mottles; few distinct black (5Y 2/1) krotivinas; massive; firm; moderately alkaline; slight reaction to 10% HCl; clear smooth boundary.
2Cg	107 – 122 cm; dark gray (5Y 4/1) loam; common distinct black (5Y 2/1) krotivinas; massive; firm; few coarse $CaCO_3$ concretions; moderately alkaline; slight reaction to 10% HCl; gradual smooth boundary.
3Cg1	122 – 147 cm; olive brown (2.5Y 4/4) and dark grayish brown (2.5Y 4/2) sandy loam; massive; friable; slight reaction to 10% HCl; strongly alkaline; gradual smooth boundary.

Horizon	Soil Description
3Cg2	147 – 183 cm; dark gray (5Y 4/1) sandy loam; few coarse prominent yellowish brown (10YR 5/8) mottles; few medium prominent olive brown (2.5Y 4/4) mottles; few medium prominent strong brown (7.5YR 4/6) concretions; massive; friable; strongly alkaline; slight reaction to 10% HCl; few medium stones.

Characterization data for well 6 on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0 – 23	14.8	26.9	27.3	31.1	7.30	2.0	0.24	12.14	7.5	0.3	1.6	0.19
A2	23 – 38	12.6	26.0	30.4	30.9	5.93	2.4	0.29	9.70	7.7	1.2	1.1	1.09
A3	38 – 51	11.1	24.8	34.3	29.9	1.77	1.8	0.21	2.68	7.8	0.5	1.1	0.45
A4	51 – 64	6.8	29.1	42.5	21.6	1.05	2.4	0.29	1.31	8.0	0.7	1.6	0.44
Bg1	64 – 76	5.2	23.2	39.6	32.0	0.91	5.1	0.62	0.50	8.2	0.4	4.4	0.09
Bg2	76 – 94	6.0	24.3	41.1	28.6	1.23	9.6	1.15	0.14	8.1	0.9	8.0	0.11
BCg	94 – 107	17.4	24.6	33.7	24.3	-	12.6	1.51	-	8.1	0.6	11.0	0.05
2Cg	107 – 122	45.4	19.2	19.6	15.7	-	12.1	1.45	-	8.3	1.7	9.5	0.18
3Cg1	122 – 147	67.7	13.7	9.2	9.4	-	12.8	1.53	-	8.5	1.7	10.2	0.17
3Cg2	147 – 183	70.8	11.2	8.4	9.5	-	14.3	1.71	-	8.6	3.0	10.3	0.29

GPS Coordinates:

42.23.7695N 93.52.8848W

Soil descriptions for well 7 on transect 1

Okoboji silty clay loam   Wetland Pond   Footslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 20 cm; black (N 2/0) silty clay loam; weak fine granular structure; friable; many fine roots; neutral; clear smooth boundary.
A2	20 – 41 cm; black (N 2/0) silty clay loam; moderate medium subangular blocky structure; friable; few fine roots; neutral; gradual smooth boundary.
A3	41 – 64 cm; black (N 2/0) silty clay loam; few fine prominent olive brown (2.5Y 4/4) mottles; few fine distinct dark gray (5Y 4/1) Fe depletions; moderate medium subangular blocky structure; firm; few fine roots; neutral; clear smooth boundary.
A4	64 – 86 cm; black (N 2/0) silty clay loam; few medium prominent olive brown (2.5Y 4/4) mottles; few medium to fine distinct dark gray (5Y 4/1) Fe depletions; few prominent brown (10YR 4/3) pore linings; moderate medium subangular blocky structure; firm; few fine roots; slightly alkaline; clear smooth boundary.
Bg	86 – 97 cm; dark gray (5Y 4/1) silty clay loam; common medium distinct black (2.5Y 2/0) organic masses on ped faces; few medium and fine prominent olive brown (2.5Y 4/4) mottles; few prominent brown (10YR 4/3) pore linings; weak fine prismatic structure; firm; very few fine roots; slightly alkaline; clear smooth boundary.
Ckg1	97 – 127 cm; light olive gray silt loam (5Y 6/2); few coarse to fine prominent olive brown (2.5Y 4/4) mottles; massive; friable; many fine $CaCO_3$ threads and concretions; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg2	127 – 140 cm; dark gray (5Y 4/1) silt loam; common coarse to fine prominent olive brown (2.5Y 4/4) mottles; massive; firm; many very fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg3	140 – 183 cm; dark gray (5Y 4/1) and light olive gray (5Y 6/2) silt loam/silty clay loam; few fine prominent olive brown (2.5Y 4/4) mottles; massive; firm; many very fine $CaCO_3$ threads; strong reaction to 10%HCl; moderately alkaline;

Characterization data for well 7 on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dol. %	Ratio
A1	0 – 20	5.2	29.1	31.6	34.1	11.56	-	-	19.88	6.6	-	-	-
A2	20 – 41	7.3	26.9	35.1	30.6	7.01	-	-	12.06	6.9	-	-	-
A3	41 – 64	3.1	19.5	40.9	36.5	2.46	5.5	0.66	3.10	7.3	0.2	4.9	0.04
A4	64 – 86	1.8	17.5	41.4	39.3	1.45	3.1	0.38	1.84	7.5	0.7	2.2	0.32
Bg	86 – 97	1.2	17.4	45.4	36.0	1.18	4.1	0.49	1.19	7.5	0.2	3.6	0.06
Ckg1	97 – 127	1.9	19.5	56.6	22.1	3.40	26.2	3.15	0.43	7.8	17.2	8.3	2.07
Ckg2	127 – 140	8.3	26.9	42.9	21.8	-	17.0	2.04	-	7.9	2.5	13.4	0.19
Ckg3	140 – 183	3.6	21.6	48.5	26.4	-	21.4	2.57	-	7.9	12.1	8.6	1.41

GPS Coordinates:

42.23.7979N 93.52.9092W

Soil descriptions for well 8 on transect 1

Wacousta mucky silt loam Wetland Pond Toeslope Position
Fine-silty, mixed, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 13 cm; black (N 2/0) silt loam/silty clay loam; moderate medium subangular blocky structure; friable; many fine roots; slightly alkaline; clear smooth boundary.
A2	13 – 23 cm; black (N 2/0) silty clay loam; many fine prominent dark grayish brown (2.5Y 4/2) masses; moderate medium subangular blocky structure; friable; common fine roots; slightly alkaline; clear smooth boundary.
Bg1	23 – 28 cm; dark grayish brown (2.5Y 4/2) silty clay loam; few black (N 2/0) organic masses on ped faces; moderate medium subangular blocky structure; friable; few fine roots; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
Bg2	28 – 41 cm; dark gray (5Y 4/1) and gray (5Y 5/1) silty clay loam; few medium prominent brown (10YR 4/3) mottles; few prominent strong brown (7.5YR 3/6) pore linings; few fine prominent strong brown (7.5YR 3/6) mottles; few medium black (N 2/0) organic masses on ped faces; moderate medium subangular blocky structure; firm; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg1	41 – 53 cm; mottled dark gray (5Y 4/1), gray (5Y 5/1), and dark grayish brown (2.5Y 4/2) silt loam; few coarse to medium prominent strong brown (7.5YR 3/6) mottles; common prominent strong brown (7.5YR 3/6) pore linings; very few black (N 2/0) organic masses on ped faces; massive; firm; many very fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg2	53 – 84 cm; gray (5Y 5/1) and dark grayish brown (2.5Y 4/2) silt loam; common prominent strong brown (7.5YR 3/6) pore linings; few fine black (N 2/0) organic masses on ped faces; massive; firm; few fine $CaCO_3$ concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg1	84 – 114 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silt loam; common prominent strong brown (7.5YR 3/6) pore linings; few fine prominent dark yellowish brown (10YR 4/4) mottles; few fine black (N 2/0) organic masses on ped faces; massive; firm; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg2	114 – 142 cm; gray (5Y 5/1) and dark gray (5Y 4/1) silt loam; common medium prominent dark yellowish brown (10YR 4/4) mottles; massive; firm; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
2Ckg	142 – 168 cm; gray (5Y 5/1) and dark grayish brown (2.5Y 4/2) silt loam/silty clay loam; few medium prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; common fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
3Ckg	168 – 183 cm; gray (5Y 5/1) and dark grayish brown (2.5Y 4/2) silty clay loam; few medium prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few fine $CaCO_3$ threads; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 9 on transect 1 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dol. %	Ratio
A1	0 – 13	4.1	22.5	49.7	23.7	8.96	4.2	0.51	14.53	7.4	0.9	3.1	0.29
A2	13 – 23	3.0	21.1	43.4	32.5	4.25	3.1	0.37	6.67	7.5	0.7	2.2	0.32
Bg1	23 – 28	1.7	16.3	48.8	33.2	1.54	8.5	1.02	0.89	7.8	0.9	7.0	0.13
Bg2	28 – 41	2.0	16.6	52.5	29.0	3.41	24.5	2.94	0.81	8.0	14.9	8.9	1.67
Ckg1	41 – 53	5.0	19.8	51.4	23.8	-	22.8	2.74	-	8.0	10.6	11.3	0.94
Ckg2	53 – 84	4.4	23.2	50.6	21.8	-	22.1	2.65	-	8.0	7.7	13.2	0.58
Cg1	84 – 114	3.3	23.9	48.8	24.1	-	22.8	2.74	-	8.0	6.1	15.4	0.40
Cg2	114 – 142	2.4	21.9	52.1	23.6	-	22.5	2.70	-	8.0	8.1	13.2	0.61
2Ckg	142 – 168	12.7	18.7	42.2	26.5	-	18.8	2.26	-	8.0	4.2	13.5	0.31
3Ckg	168 - 183	4.0	16.8	50.2	29.1	-	17.8	2.13	-	7.9	4.7	12.0	0.39

GPS Coordinates:

42.23.8677N 93.52.9531W

Soil descriptions for well 1 on transect 2

Nicollet clay loam Upland Prairie Shoulder Slope Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
A1	0 – 18 cm; black (5Y 2/1) clay loam; weak fine subangular blocky structure; friable; many medium and common fine roots; 3-5% fine gravel; moderately acid; clear smooth boundary.
A2	18 – 33 cm; black (5Y 2/2) clay loam; moderate fine subangular block structure; friable; common medium and few fine roots; 3-5% fine gravel; moderately acid; clear smooth boundary.
AB	33 – 43 cm; black (5Y 2/2) and dark grayish brown (2.5Y 4/2) clay loam; moderate medium subangular blocky structure; friable; few medium and fine roots; 3% fine gravel; moderately acid; abrupt smooth boundary.
Bw	43 – 64 cm; dark grayish brown (2.5Y 4/2) clay loam; common fine distinct black (2/5Y 2/2) organic masses on ped faces; moderate medium subangular blocky structure; firm; few medium and fine roots; <3% fine gravel; neutral; clear smooth boundary.
Bg	64 – 79 cm; dark grayish brown (2.5Y 4/2) and brown (10YR 4/3) loam/clay loam; few fine prominent yellowish brown (10YR 5/8) mottles; moderate medium subangular blocky structure; firm; few fine roots; few medium stones; neutral; abrupt smooth boundary.
2Ckg	79 – 84 cm; olive brown (2.5Y 4/4) loam; few fine prominent yellowish brown (10YR 5/8) and medium distinct dark grayish brown (2.5Y 4/2) and brown (10YR 4/3) mottles; weak fine subangular blocky structure; friable; common fine $CaCO_3$ threads; few fine roots; few medium stones; strong effervescence with 10% HCl; slightly alkaline; abrupt smooth boundary.
3Ckg1	84 – 99 cm; dark grayish brown (2.5Y 4/2) and brown (10YR 4/3) loam; few fine distinct olive brown (2.5Y 4/4) mottles; moderate medium subangular blocky structure; firm; few fine $CaCO_3$ concretions; few fine roots; few medium stones; strong effervescence with 10% HCl; moderately aklakine; clear smooth boundary.
3Ckg2	99 – 112 cm; gray (5Y 5/1) loam; few coarse prominent yellowish brown (10YR 5/8) mottles; massive; firm; common fine $CaCO_3$ threads and concretions; strong effervescent with 10% HCl; moderately alkaline; clear smooth boundary.
4Cg	112 – 124 cm; light olive brown (2.5Y 5/4) loam; few fine prominent yellowish brown (10YR 5/8) mottles; few medium prominent (5Y 4/1) Fe depletions; few medium distinct olive brown (2.5Y 4/2) mottles; massive; friable; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
5Ckg	124 – 158 cm; gray (5Y 5/1) silt loam; few medium prominent light olive brown (2.5Y 5/4) mottles; few fine prominent strong brown (7.5YR 4/6) mottles; massive; friable; sand lenses between peds; common very fine Mn concretions; few medium $CaCO_3$ nodules; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
6Cg	158 – 170 cm; yellowish brown (10YR 5/4) loam; few fine prominent gray (5Y 5/1) Fe depletions; massive; friable; common fine Mn nodules; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
7Ckg	170 – 203 cm; yellowish brown (10YR 5/4) silt loam; common medium distinct yellowish brown (10YR 5/8) mottles; few medium gray (5Y 5/1) Fe depletions; prominent strong brown (7.5YR 4/6) pore linings; massive; friable; fewfine $CaCO_3$ concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
7Cg	203 – 226 cm; light olive gray (5Y 6/2) silt loam; few medium prominent yellowish brown (10YR 5/8) mottles; massive; friable; few fine Mn concretions; moderately alkaline; strong reaction to 10% HCl.

Characterization data for well 1 on transect 2 in Gordon's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	O.M	pH	Calcite	Dol.	Ratio
	cm	%	%	%	%	%	%	%	%		%	%	
A1	0 – 18	37.9	15.3	17.0	29.8	2.27	-	-	3.86	5.8	-	-	-
A2	18 – 33	32.3	20.3	16.3	31.1	1.99	-	-	3.38	5.8	-	-	-
AB	33 – 43	32.1	15.5	22.1	30.2	1.47	-	-	2.50	6.0	-	-	-
Bw	43 – 64	34.9	14.2	21.7	29.2	1.21	-	-	2.06	6.6	-	-	-
Bg	64 – 79	37.2	14.5	22.1	26.2	0.77	-	-	1.31	6.9	-	-	-
2Ckg1	79 – 84	47.2	14.6	19.9	18.3	1.84	13.2	1.58	0.44	7.7	3.8	8.7	0.44
3Ckg1	84 – 99	33.0	18.7	30.0	18.3	2.33	16.8	2.01	0.54	8.0	5.7	10.2	0.56
3Ckg2	99 – 112	34.8	16.8	29.6	18.8	-	20.3	2.44	-	8.0	7.2	12.1	0.60
4Cg	112 – 124	48.7	14.3	21.9	15.1	-	19.4	2.33	-	8.1	5.8	12.5	0.46
5Ckg	124 – 158	17.0	22.4	43.6	17.0	-	21.1	2.53	-	8.2	5.8	14.1	0.41
6Cg	158 – 170	44.6	27.7	16.6	11.1	-	20.8	2.5	-	8.3	3.5	16.0	0.22
7Ckg	170 – 203	7.0	28.2	50.0	14.8	-	23.1	2.78	-	8.3	4.5	17.1	0.26
7Cg	203 - 226	8.5	29.8	46.6	15.1	-	24.5	2.94	-	8.1	4.0	18.9	0.21

GPS Coordinates:

42.23.4727N 93.53.0420W

Soil descriptions for well 2 on transect 2

Webster clay loam   Upland Prairie   Backslope Position
Fine-loamy, mixed, superactive, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 23 cm; black (2.5Y 2/0) clay loam; few fine prominent yellowish brown (10YR 5/8) mottles; weak fine subangular blocky structure; friable; common medium and many fine roots; 2-5% fine gravel; slightly acid; clear smooth boundary.
A2	23 – 46 cm; black (2.5Y 2/0) clay loam; common fine distinct dark grayish brown (2.5Y 4/2) Fe depletions; few fine prominent yellowish brown (10YR 5/8) mottles; moderate medium subangular blocky structure; friable; common fine roots; 3% fine gravel; common fine and medium stones; slightly alkaline; clear smooth boundary.
Bg	46 – 61 cm; dark gray (5Y 4/1) clay loam; few fine prominent yellowish brown (10YR 5/8) mottles; common medium black (2.5Y 2/0) organic coatings on ped faces; few fine distinct dark grayish brown (2.5Y 4/2) mottles; moderate medium subangular blocky structure; firm; few fine roots; 2% fine gravel; moderately alkaline; slight reaction to 10% HCl; clear smooth boundary.
Bkg	61 – 81 cm; dark gray (5Y 4/1) loam; few fine distinct dark grayish brown (2.5Y 4/2) mottles; few medium prominent yellowish brown (10YR 5/8) mottles; few medium black (2.5Y 2/1) organic coatings on ped faces; moderate coarse and medium subangular blocky structure; firm; few fine roots; few coarse $CaCO_3$ streaks; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Ckg1	81 – 122 cm; gray (5Y 5/1) loam; many coarse prominent dark yellowish brown (10YR 4/6) mottles; weak fine prismatic structure; firm; common fine $CaCO_3$ masses and streaks; few fine roots; few fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Ckg2	122 – 168 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; few medium and coarse prominent dark yellowish brown (10YR 4/6); few prominent dark yellowish brown (10YR 4/6) pore linings; massive; firm; common $CaCO_3$ streaks; few coarse and medium stones; strong reaction to 10% HCl; strongly alkaline; clear smooth boundary.
Cg	168 – 208 cm; light olive brown (2.5Y 5/4) loam; few coarse prominent gray (5Y 4/1) Fe depletions; few fine prominent yellowish brown (10YR 5/8) mottles; massive; firm; common fine Mn concretions; few fine and medium stones; moderately alkaline; strong reaction to 10% HCl.

Characterization data for well 2 on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dol. %	Ratio
A1	0 – 23	38.0	15.9	18.7	27.5	2.63	-	-	4.53	6.5	-	-	-
A2	23 – 46	36.3	13.9	19.0	30.8	1.20	1.8	0.21	1.71	7.5	0.5	1.1	0.45
Bg	46 – 61	39.6	14.1	18.4	27.9	2.13	10.2	1.23	1.54	7.9	1.1	8.4	0.13
Bkg	61 – 81	40.5	15.1	20.3	24.1	2.12	16.4	1.97	0.26	8.1	4.0	11.4	0.35
Ckg1	81 – 122	42.3	15.2	20.7	21.8	-	20.4	2.45	-	8.4	7.5	11.9	0.63
Ckg2	122 – 168	40.7	15.2	21.6	22.5	-	19.9	2.38	-	8.5	6.2	12.6	0.49
Cg	168 – 208	43.5	15.3	21.3	19.8	-	18.7	2.24	-	8.4	6.2	11.5	0.54

GPS Coordinates:

42.23.4861N 93.53.0039W

Soil descriptions for well 3 on transect 2

Canisteo loam Wet Prairie Backslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 25 cm; black (N 2/0) loam; weak fine subangular blocky structure; friable; common medium and many fine roots; 3-5% fine gravel; neutral; clear smooth boundary.
A2	25 – 46 cm; black (N 2/0) loam; few fine prominent dark grayish brown (2.5Y 4/2) Fe depletions; moderate medium subangular blocky structure; friable; few medium and many fine roots; 2-3% fine gravel; few medium stones; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
Bkg1	46 – 66 cm; dark grayish brown (2.5Y 4/2) loam; common medium black (N 2/0) organic coatings on ped faces; weak fine prismatic structure; slightly firm; few fine roots; $CaCO_3$ masses on ped faces; few medium stones; 1% fine gravel; slight reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bkg2	66 – 76 cm; dark gray (5Y 4/1) and dark grayish brown (2.5Y 4/2) loam; few medium and fine prominent dark yellowish brown (10YR 4/6) mottles; moderate medium subangular blocky structure; firm; few fine roots; few $CaCO_3$ masses on ped faces; moderate reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg1	76 – 99 cm; gray (5Y 5/1) loam; common medium to coarse prominent dark yellowish brown (10YR 4/6) mottles; black (2.5Y 2/0) krotovinas; massive; firm; few medium and common fine stones; common very fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
Cg2	99 – 109 cm; dark yellowish brown (10YR 4/6) and olive brown (2.5Y 4/4) loam; few fine and medium prominent gray (5Y 5/1) Fe depletions; massive; firm; few medium stones; few sand lenses in pores; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg3	109 – 140 cm; gray (5Y 5/1) loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; common medium prominent olive brown (2.5Y 4/4) mottles; massive; firm; few medium Mn concretions; few medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg4	140 – 145 cm; olive brown (2.5Y 4/4) loam; few medium prominent gray (5Y 5/1) Fe depletions; few very fine prominent strong brown (7.5YR 4/6) concretions; strong brown (7.5YR 4/6) pore linings; massive; firm; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
Cg5	145 – 150 cm; gray (5Y 5/1) loam; few medium prominent strong brown (7.5YR 4/6) mottles; few medium prominent olive brown (2.5Y 4/4) mottles; few very fine prominent strong brown (7.5YR 4/6) concretions; few very fine Mn concretions; massive; firm; few fine stones; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.

Horizon	Soil Description
2Cg	150 – 165 cm; gray (5Y 5/1) loam; many fine to medium olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few medium to fine stones; few very fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg1	165 – 216 cm; olive brown (2.5Y 4/4) loam; common medium and coarse prominent strong brown (7.5YR 4/6) mottles; prominent strong brown (7.5YR 4/6) pore linings; few medium prominent gray (5Y 5/1) Fe depletions; massive; firm; few very fine Mn concretions; few fine and medium stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg2	216 – 229 cm; dark gray (5Y 4/1) and olive gray (5Y 4/2) loam; few coarse to medium prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few medium and coarse stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 3 on transect 2 in Gordon's Marsh.

Horizon	Depth	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0 – 25	38.7	15.8	19.6	26.0	3.14	3.8	0.45	4.63	7.3	0.7	2.9	0.24
A2	25 – 46	43.0	14.7	17.0	25.3	2.34	5.6	0.67	2.87	7.7	1.1	4.1	0.27
Bkg1	46 – 66	43.0	14.8	17.3	24.9	1.79	9.1	1.09	1.20	7.7	0.9	7.5	0.12
Bkg2	66 – 76	44.6	14.4	18.5	22.5	2.02	15.9	1.91	0.19	7.9	2.9	12.0	0.24
Cg1	76 – 99	45.5	14.5	19.8	20.3	-	16.9	2.03	-	8.1	4.7	11.3	0.42
Cg2	99 – 109	43.9	14.1	20.9	21.1	-	20.5	2.46	-	8.1	7.0	12.4	0.56
Cg3	109 – 140	43.7	14.1	21.2	21.0	-	19.5	2.34	-	8.1	5.5	12.9	0.43
Cg4	140 – 145	40.6	14.4	23.1	21.8	-	19.5	2.34	-	8.2	6.1	12.3	0.50
Cg5	145 – 150	41.8	14.2	22.6	21.3	-	17.8	2.13	-	8.3	4.4	12.3	0.36
2Cg	150 – 165	30.3	16.3	31.5	21.9	-	21.1	2.53	-	8.2	5.6	14.2	0.39
3Cg1	165 – 216	39.7	17.5	22.9	19.9	-	20.6	2.48	-	8.1	4.8	14.6	0.33
3Cg2	216 – 229	42.2	15.1	21.7	21.0	-	19.1	2.29	-	8.1	5.1	12.9	0.40

GPS Coordinates:

42.23.4990N 93.53.9824W

Soil descriptions for well 4 on transect 2

Canisteo loam Wet Prairie II Footslope Position
Fine-loamy, mixed, superactive, mesic, calcareous Typic Endoaquoll

Horizon	Soil Description
A1	0 – 20 cm; black (N 2/0) loam; weak medium subangular blocky structure; friable; common medium and many fine roots; 2-3% fine gravel; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
A2	20 – 48 cm; black (2.5Y 2/1) loam; few medium and fine distinct dark grayish brown (2.5Y 4/2) Fe depletions; moderate fine subangular blocky structure; friable; few medium and common fine roots; 2-3% fine gravel; strong reaction to 10% HCl; slightly alkaline; abrupt smooth boundary.
Bg	48 – 79 cm; mottled dark gray (5Y 4/1), gray (5Y 5/1) and light olive gray (5Y 6/2) loam; few fine and medium prominent yellowish brown (10YR 5/8) mottles; moderate medium subangular blocky structure; firm; few medium and fine roots; <2% fine gravel; few medium and coarse stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Ckg1	79 – 102 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; few medium and coarse prominent yellowish brown (10YR 5/8) mottles; common fine prominent strong brown (7.5YR 4/6) concretions; weak fine prismatic structure; firm; few fine roots; few $CaCO_3$ masses on ped faces; few medium and coarse stones; common fine Mn concretions; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Ckg2	102 – 122 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; few medium an coarse prominent yellowish brown (10YR 5/8) mottles; massive; friable; few fine $CaCO_3$ concretions; sand lenses between ped faces; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
Cg1	122 – 142 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common medium prominent yellowish brown (10YR 5/8) and olive brown (2.5Y 4/4) mottles; few coarse and medium prominent strong brown (7.5YR 4/6) concretions; few coarse faint dark gray (5Y 4/1) masses; massive; firm; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
Cg2	142 – 165 cm; olive brown (2.5Y 4/4) sandy loam/lloam; few fine and medium prominent dark yellowish brown (10YR 4/6) mottles; few fine prominent strong brown (7.5YR 4/6) concretions; few medium prominent gray (5Y 5/1) Fe depletions; massive; firm; few fine and medium stones; few medium Mn concretions; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.
2Cg1	165 – 180 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common medium prominent olive brown (2.5Y 4/4) mottles; few very fine prominent dark yellowish brown (10YR 4/6) and strong brown (7.5YR 5/6) mottles; massive; firm; few medium and fine stones; strong reaction to 10% HCl; slightly alkaline; clear smooth boundary.

Horizon	Soil Description
2Cg2	180 – 218 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common medium prominent strong brown (7.5YR 4/5) mottles; massive; firm; strong reaction to 10% HCl; slightly alkaline; gradual smooth boundary.
2Cg3	218 – 234 cm; dark gray (5Y 4/1) and olive gray (5Y 4/2) loam; common medium prominent olive brown (2.5Y 4/4) and strong brown (7.5YR 4/6) mottles; massive; firm; few medium and fine stones; slightly alkaline.

Characterization data for well 4 on transect 2 in Gordon's Marsh.

Horizon	Depth	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0 – 20	40.3	15.6	18.9	25.2	3.75	11.5	1.38	4.08	7.9	1.8	9.0	0.20
A2	20 – 48	42.0	16.1	18.8	23.1	3.50	13.2	1.59	2.40	8.1	2.6	9.8	0.27
Bg	48 – 79	43.1	15.8	19.5	21.5	2.32	16.0	1.91	0.71	8.2	6.4	8.8	0.73
Ckg1	79 – 102	49.6	16.9	18.2	15.3	2.47	24.8	2.98	-	8.3	7.6	15.9	0.48
Ckg2	102 – 122	50.9	17.1	19.2	12.8	2.33	19.6	2.35	-	8.3	5.1	13.4	0.38
Cg1	122 – 142	50.9	16.4	17.5	15.1	2.90	27.5	3.30	-	8.2	9.6	16.5	0.58
Cg2	142 – 165	54.5	14.2	17.8	13.5	2.38	22.0	2.64	-	8.3	5.9	14.8	0.40
2Cg1	165 – 180	45.7	18.2	20.5	15.6	2.53	22.4	2.69	-	8.3	6.8	14.4	0.47
2Cg2	180 – 218	43.0	16.1	22.2	18.7	2.03	17.5	2.11	-	8.2	4.7	11.8	0.40
2Cg3	218 – 234	43.4	17.0	19.7	19.9	2.41	19.0	2.28	-	8.1	5.8	12.2	0.48

GPS Coordinates:

42.23.5215N93.53.9473W

Soil descriptions for well 5 on transect 2

Canisteo clay loam   Cattail (*Carex* sp) Wetland Zone   Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
Ak	0 – 20 cm; black (N 2/0) clay loam; few fine prominent dark grayish brown (2.5Y 4/2) pore linings; weak fine subangular blocky structure; friable; common medium and many fine roots; 3% fine gravel; slightly alkaline; abrupt smooth boundary.
A	20 – 61 cm; black (N 2/0) clay loam; dark yellowish brown (10YR 4/6) pore linings; weak medium subangular blocky structure; friable; few medium and common fine roots; 3% fine gravel; slightly alkaline; clear smooth boundary.
Bg1	61 – 79 cm; very dark gray (2.5Y 3/1) clay loam; moderate fine subangular blocky structure; friable; common fine roots; 1-2% fine gravel; moderately alkaline; clear smooth boundary.
Bg2	79 – 102 cm; mottled gray (5Y 5/1), light olive gray (5Y 6/2), and black (5Y 2/1) silty clay loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; moderate fine prismatic structure; firm; few fine roots; moderately alkaline; abrupt smooth boundary.
2Ckg	102 – 122 cm; gray (5Y 5/1) loam; few medium prominent olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; common very fine prominent strong brown (7.5YR 4/6) concretions; massive; firm; few fine roots; few medium $CaCO_3$ concretions; common very fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg	122 – 155 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common fine prominent dark yellowish brown (10YR 4/6) mottles; few fine prominent olive brown (2.5Y 4/4) mottles; black (N 2/0) krotovinas; massive; firm; few medium and coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg1	155 – 203 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common medium prominent olive brown (2.5Y 4/4) mottles; few fine prominent strong brown (7.5YR 4/6) mottles; massive; firm; few fine Mn concretions; few fine to coarse stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Cg2	203 – 226 cm; dark gray (5Y 4/1) and dark grayish brown (2.5Y 4/2) loam; few fine prominent yellowish brown (10YR 5/8); massive; firm; few fine Mn concretions; few fine stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 5 on transect 2 in Gordon's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OM	pH	Calcite	Dol.	Ratio
	cm	%	%	%	%	%	%	%	%		%	%	
Ak	0 – 20	28.6	19.7	23.2	28.6	3.85	19.2	2.31	2.65	7.5	1.2	16.6	0.07
A	20 – 61	25.4	17.6	26.6	30.5	1.67	3.6	0.43	2.13	7.8	0.9	2.4	0.38
Bg1	61 – 79	29.3	13.1	26.1	31.4	1.00	5.1	0.61	0.67	7.9	0.6	4.1	0.15
Bg2	79 – 102	20.0	19.3	31.9	28.8	1.20	10.9	1.30	-	8.0	1.1	9.0	0.12
2Ckg	102 – 122	38.4	14.7	23.2	23.7	2.10	15.9	1.91	-	8.1	2.7	12.2	0.22
2Cg	122 – 155	37.4	15.6	23.9	23.2	1.87	16.0	1.92	-	8.1	4.0	11.1	0.36
3Cg1	155 – 203	42.5	14.7	21.9	20.9	2.29	18.7	2.25	-	8.2	4.6	13.0	0.35
3Cg2	203 – 226	42.2	15.1	22.0	20.6	2.36	22.8	2.74	-	8.1	6.0	15.5	0.39

GPS Coordinates:
42.23.5361N93.53.9258W

Soil descriptions for well 6 on transect 2

Okoboji silty clay loam Pond Depression Toeslope Position
Fine, smectitic, mesic Cumulic Vertic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) silty clay loam; weak fine granular structure; friable; common fine and many very fine roots; few coarse rhizomes; 2% fine gravel; neutral; clear smooth boundary.
A2	15 – 36 cm; black (2.5Y 2/0) silty clay loam; few fine prominent olive gray (5Y 5/2) Fe depletions; weak fine subangular blocky structure; friable; many very fine and few fine roots; neutral; abrupt smooth boundary.
A3	36 – 56 cm; black (2.5Y 2/0) silty clay loam; common fine prominent olive gray (5Y 5/2) Fe depletions; common fine prominent olive (5Y 4/3) mottles; weak fine subangular blocky structure; slightly firm; few fine roots; slightly alkaline; abrupt smooth boundary.
ABg	56 – 66 cm; black (2.5Y 2/0) and very dark gray (5Y 3/1) silty clay loam; common fine prominent olive (5Y 4/3) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; moderate fine prismatic structure; firm; slightly alkaline; gradual smooth boundary.
Bkg	66 – 84 cm; dark gray (5Y 4/1) silty clay loam; many fine prominent dark yellowish brown (10YR 4/6) mottles; few fine prominent olive (5Y 4/3) mottles; moderate fine prismatic structure; firm; few very coarse black (N 2/0) krotovinas; few fine $CaCO_3$ threads between ped faces; slight reaction to 10% HCl; moderately alkaline; clear smooth boundary.
Cg	84 – 91 cm; dark gray (5Y 4/1) and gray (5Y 5/1) silt loam; common fine prominent dark yellowish brown (10YR 4/6) mottles; few medium prominent olive (5Y 4/3) and olive brown (2.5Y 4/4) mottles; moderate medium prismatic structure; firm; moderately alkaline; clear smooth boundary.
2Cg1	91 – 109 cm; gray (5Y 5/1) loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; few medium prominent olive brown (2.5Y 4/4) mottles; massive; firm; moderate reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Cg2	109 – 157 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common fine prominent dark yellowish brown (10YR 4/6) mottles; few fine prominent olive brown (2.5Y 4/4) mottles; massive; firm; strong reaction to 10% HCl; strongly alkaline; clear smooth boundary.
3Cg1	157 – 170 cm; dark gray (5Y 4/1) and dark grayish brown sandy loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; common medium prominent olive brown (2.5Y 4/4) mottles; massive; firm; few to coarse stones; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
3Cg2	170 – 198 cm; gray (5Y 5/1) sandy loam; few fine prominent olive brown (2.5Y 4/4) mottles; massive; friable; strong reaction to 10% HCl; strongly alkaline; gradual smooth boundary.

Horizon	Soil Description
4Cg	198 – 211 cm; dark grayish brown (2.5Y 4/2) and olive brown (2.5Y 4/4) loamy sand; few fine prominent dark yellowish brown (10YR 4/6) and strong brown (7.5YR 4/6) mottles; massive; friable; strong reaction to 10%HCl; strongly alkaline; clear smooth boundary.
5Cg	211 – 231 cm; dark grayish brown (2.5Y 4/2), olive brown (2.5Y 4/4), and gray (5Y 5/1) sandy loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few medium and coarse stones; strong reaction to 10% HCl; strongly alkaline.

Characterization data for well 6 on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
A1	0 – 15	10.6	25.9	29.2	34.3	4.77	-	-	8.20	6.8	-	-	-
A2	15 – 36	8.6	19.5	37.9	34.0	1.92	1.8	0.21	2.94	7.2	0.1	1.6	0.06
A3	36 – 56	6.0	18.0	38.0	38.0	2.09	4.5	0.54	1.85	7.5	1.1	3.1	0.35
ABg	56 – 66	5.4	17.4	42.2	35.0	2.26	12.4	1.48	1.30	7.8	0.6	10.9	0.06
Bkg	66 – 84	6.4	19.2	41.0	33.5	1.84	12.3	1.47	0.64	7.9	2.2	9.3	0.24
Cg	84 – 91	14.9	31.8	32.3	21.0	-	11.6	1.40	-	8.1	0.8	10.0	0.08
2Cg1	91 – 109	45.2	25.2	18.6	11.1	-	26.1	3.13	-	8.4	5.0	19.4	0.26
2Cg2	109 – 157	48.7	14.0	20.3	17.0	-	18.0	2.17	-	8.5	3.8	13.1	0.29
3Cg1	157 – 170	60.2	18.1	13.4	8.3	-	20.6	2.47	-	8.3	5.2	14.2	0.37
3Cg2	170 – 198	54.8	17.7	16.9	10.6	-	19.9	2.39	-	8.5	5.2	13.5	0.39
4Cg	198 – 211	81.0	7.9	5.7	5.3	-	12.5	1.50	-	8.6	3.6	8.2	0.44
5Cg	211 – 231	55.3	14.9	17.2	12.6	-	20.2	2.43	-	8.5	5.4	13.6	0.40

GPS Coordinates:

42.23.5547N 93.53.9482W

Soil descriptions for well 1 on transect 3

Nicollet clay loam Alfalfa Food Plot Summit Slope Position
Fine-loamy, mixed, superactive, mesic Aquic Hapludoll

Horizon	Soil Description
Ap	0 – 25 cm; black (10YR 2/1) clay loam; weak fine subangular blocky structure; friable; common fine to very fine roots; 2-5% fine gravel; strongly acid; clear smooth boundary.
A	25 – 41 cm; black (10YR 2/1) clay loam; common fine faint very dark gray (10YR 3/1) masses on ped faces; weak fine subangular blocky structure; friable; few fine to very fine roots; 2-5% fine gravel; moderately acid; abrupt smooth boundary.
Bw1	41 – 53 cm; dark grayish brown (10YR 4/2) clay loam; common fine faint very dark gray (10YR 3/1) masses on ped faces; weak fine subangular blocky structure; friable; few fine to very fine roots; 2% fine gravel; slightly acid; abrupt smooth boundary.
Bw2	53 – 69 cm; dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) clay loam/loam; few fine faint very dark gray (10YR 3/1) masses on ped faces; weak fine prismatic structure; friable; few fine to very fine roots; 2-5% fine gravel; neutral; gradual smooth boundary.
Bg1	69 – 84 cm; dark grayish brown (2.5Y 4/2) loam; few fine distinct light olive brown (2.5Y 5/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; black (10YR 2/1) krotovinas; weak medium prismatic structure; friable; very few fine roots; 2% fine gravel; neutral; clear smooth boundary.
Cg	89 – 102 cm; dark grayish brown (2.5Y 4/2) and grayish brown (2.5Y 5/2) loam; few fine distinct light olive brown (2.5Y 5/4) mottles; common fine prominent yellowish brown (10YR 4/6) mottles; few very dark (10YR 3/1) masses on ped faces; moderate medium prismatic structure; very few fine roots; 2% fine gravel; few fine Mn concretions; slightly alkaline; abrupt smooth boundary.
2Ckg	102 – 127 cm; grayish brown (2.5Y 5/2) silt loam; few fine prominent dark brown (7.5YR 3/2) mottles; many medium to fine prominent light olive brown (2.5Y 5/6) mottles; few fine prominent yellowish brown (10YR 4/6) mottles; massive; slightly firm; dark brown (7.5YR 3/2) concretions between peds; $CaCO_3$ streaks; strong reaction to 10%HCl; moderately alkaline; clear smooth boundary.
2Cg	127 – 152 cm; olive gray (5Y 5/2) silt loam; common medium prominent yellowish brown (10YR 4/6) mottles; common medium and few coarse light olive brown (2.5Y 5/6) mottles; platy structure; firm; sand grains between peds; common fine dark brown (7.5YR 3/2) nodules; few fine Mn concretions; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
3Cg	152 – 165 cm; grayish brown (2.5Y 5/2) and olive brown (2.5Y 4/4) sandy loam; many medium prominent yellowish brown (10YR 4/6) mottles; massive; friable; slight reaction to 10% HCl; moderately alkaline; abrupt wavy boundary.

Horizon	Soil Description
4Ckg	165 – 193 cm; grayish brown (2.5Y 5/2) loam; many medium prominent light olive brown (2.5Y 5/6) mottles; common fine prominent yellowish brown (10Y 4/6) mottles; platy structure; slightly firm; few fine Mn concretions; $CaCO_3$ streaks; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
5Ckg	193 – 211 cm; light brownish gray (2.5Y 6/2) and grayish brown (2.5Y 5/2) silt loam; few coarse gray (5Y 5/1) Fe depletions; few coarse to medium strong brown (7.5YR 4/6) mottles; platy structure; firm; few fine stones; few very fine Mn concretions; few $CaCO_3$ masses; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
6Cg	211 – 218 cm; gray (5Y 5/1) and light brownish gray silt loam; common fine prominent light olive brown (2.5Y 5/6) mottles; few fine prominent yellowish brown (10YR 4/6) mottles; massive; firm; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
7Cg	218 – 229 cm; light olive brown (2.5Y 5/4) and olive brown (2.5Y 4/4) silt loam; few fine gray (5Y 5/1) Fe depletions; massive; firm; few fine stones; strong reaction to 10% HCl; moderately alkaline.

Selected soil characterization data for well 1 on transect 3 in Gordon's Marsh.

Horizon	Depth	Sand	Coarse Silt	Fine Silt	Clay	TC	CCE	IC	OM	pH	Calcite	Dol.	Ratio
	cm	%	%	%	%	%	%	%	%		%	%	
Ap	0 – 25	23.4	21.0	25.7	29.9	2.50	-	-	4.30	5.3	-	-	-
A	25 – 41	28.2	18.8	23.1	30.0	1.56	-	-	2.68	6.0	-	-	-
Bw1	41 – 53	33.6	13.3	22.3	30.8	0.84	-	-	1.44	6.4	-	-	-
Bw2	53 – 69	34.9	16.3	21.5	27.3	0.50	-	-	0.86	6.7	-	-	-
Bg1	69 – 84	35.2	23.3	17.3	24.2	0.41	4.8	0.57	-	7.1	1.4	3.1	0.45
Cg	84 – 102	35.0	17.2	27.6	20.2	0.59	4.5	0.55	-	7.7	0.7	3.6	0.19
2Ckg	102 – 127	21.3	28.6	35.2	14.9	-	23.7	2.84	-	8.2	5.5	16.7	0.33
2Cg	127 – 152	30.6	23.7	30.6	15.1	-	20.0	2.39	-	8.2	4.7	14.0	0.34
3Cg	152 – 165	59.6	12.6	16.7	11.1	-	22.9	2.75	-	8.4	4.8	16.7	0.29
4Ckg	165 – 193	37.8	23.5	25.4	13.3	-	18.8	2.26	-	8.2	4.3	13.4	0.32
5Ckg	193 – 211	25.4	18.7	38.1	17.7	-	22.2	2.67	-	8.2	4.9	16.0	0.31
6Cg	211 – 218	16.7	21.2	41.8	20.4	-	20.0	2.40	-	8.2	4.0	14.7	0.27
7Cg	218 – 229	30.6	26.8	31.8	10.9	-	24.3	2.92	-	8.3	4.6	18.2	0.25

GPS Coordinates:

42.23.6929N 93.52.6787W

Soil descriptions for well 2 on transect 3

Delft clay loam Mowed Trail Adjacent to Alfalfa Food Plot Summit Slope Position
Fine-silty, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 13 cm; black (7.5YR 2/0) clay loam; weak fine granular structure; friable; many very fine and common fine roots; 5% fine gravel; moderately acid; clear smooth boundary.
A2	13 – 38 cm; black (7.5YR 2/0) silty clay loam; weak fine subangular blocky structure; slightly firm; common very fine and few fine roots; 2-55 fine gravel; moderately acid; abrupt smooth boundary.
A3	38 – 58 cm; black (2.5Y 2/0) silty clay loam; weak fine granular; friable; few fine and very fine roots; 2-5% fine gravel; moderately acid; abrupt smooth boundary.
A4	58 – 74 cm; very dark gray (2.5Y 3/1) silty clay loam; weak fine subangular blocky structure; friable; few fine roots; 2% fine gravel; moderately acid; clear smooth boundary.
A5	74 – 86 cm; very dark gray (10YR 3/1) silty clay loam; few fine distinct dark grayish brown (2.5Y 4/2) Fe depletions; black (2.5Y 2/0) krotovinas; weak fine subangular blocky structure; friable; very few fine roots; moderately acid; clear smooth boundary.
AB	86 – 102 cm; 50% dark grayish brown (2.5Y 4/2) and 50% very dark gray (2.5Y 3/1) silty clay loam; very few fine prominent dark yellowish brown (10YR 4/4) mottles; moderate fine subangular blocky structure; friable; very few fine roots; moderately acid; clear smooth boundary.
2Bg1	102 – 117 cm; 75% dark grayish brown (2.5Y 4/2) and 25% very dark gray (2.5Y 3/1) clay loam; few fine prominent dark yellowish brown (10YR 4/4) and dark yellowish brown (10YR 4/6) mottles; moderate medium subangular blocky structure; slightly firm; few stones; 2% fine gravel; slightly acid; clear smooth boundary.
2Bg2	117 – 137 cm; dark gray (5Y 4/1) and olive gray (5Y 5/2) clay loam; few fine prominent olive brown (2.5Y 4/4) mottles; massive structure; firm; few Mn concretions; few stones; slightly acid; clear smooth boundary.
2Bg3	137 – 155 cm; gray (5Y 5/1) and olive gray (5Y 5/2) clay loam; many fine prominent olive brown (2.5Y 4/4) mottles; few very fine to fine very dark gray (10YR 3/1) krotovinas; massive; firm; few coarse to fine stones; neutral; clear smooth boundary.
2Cg	155 – 178 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) clay loam/loam; common fine prominent olive brown (2.5Y 4/4) and light olive brown (2.5Y 5/4) mottles; massive; firm; few medium dark brown (7.5YR 3/4) nodules; common black (2.5Y 2/0) krotovinas; few coarse to fine stones; slightly alkaline; gradual smooth boundary.

Horizon	Soil Description
2Ckgl	178 – 201 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common fine prominent light olive brown (2.5Y 5/4) mottles; few medium to fine strong brown (7.5YR 4/6) mottles; massive; firm; many very fine very dark gray (10YR 3/1) krotovinas; common fine $CaCO_3$ concretions; few fine to coarse stones; moderate reaction to 10% HCl; moderately alkaline; clear smooth boundary.
2Ckg2	201 – 226 cm; gray (5Y 5/1) and light olive gray (5Y 6/2) loam; common fine prominent light olive brown (2.5Y 5/4) mottles; massive; firm; few very fine to fine very dark gray (10YR 3/1) krotovinas; few fine $CaCO_3$ concretions; few coarse and medium strong brown (7.5YR 4/6) concretions; moderately alkaline.

Characterization data for well 2 on transect 2 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coa. Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	pH	Calcite %	Dol. %	Ratio	Lab Texture
A1	0 – 13	21.5	21.7	28.0	28.9	4.43	-	-	5.8	-	-	-	CL
A2	13 – 38	15.8	20.4	32.3	31.6	3.66	-	-	5.9	-	-	-	SiCL
A3	38 – 58	11.9	19.3	35.4	33.5	3.01	-	-	5.8	-	-	-	SiCL
A4	58 – 74	11.5	18.8	35.6	34.1	2.28	-	-	6.0	-	-	-	SiCL
A5	74 – 86	13.3	18.0	34.5	34.2	2.41	-	-	5.8	-	-	-	SiCL
AB	86 – 102	13.2	16.1	33.2	37.5	1.30	-	-	6.0	-	-	-	CL
2Bgl	102 – 117	29.8	12.3	22.9	34.9	0.47	-	-	6.1	-	-	-	CL
2Bg2	117 – 137	35.5	13.7	19.2	31.6	0.35	-	-	6.3	-	-	-	CL
2Bg3	137 – 155	37.2	13.7	19.0	30.1	0.38	-	-	6.7	-	-	-	CL
2Cg	155 – 178	37.7	14.9	20.8	26.6	-	17.1	2.06	7.5	0.6	15.2	0.04	L
2Ckgl	178 – 201	37.5	16.4	23.4	22.7	-	15.9	1.90	7.9	3.0	11.9	0.25	L
2Ckg2	201 – 226	36.6	18.0	24.1	21.2	-	17.1	2.06	8.2	3.8	12.2	0.31	L

GPS Coordinates:

42.23.6704N 93.52.6777W

Soil descriptions for well 3 on transect 3

Delft loam Cedar-Oak Forest Plot Backslope Position
Fine-loamy, mixed, superactive, mesic Cumulic Endoaquoll

Horizon	Soil Description
A1	0 – 20 cm; black (7.5YR 2/0) loam; moderate fine subangular blocky structure; friable; few medium and many fine to very fine roots; 5% fine gravel; slightly acid; gradual smooth boundary.
A2	20 – 36 cm; black (2.5Y 2/1) loam/clay loam; moderate fine subangular blocky structure; friable; common fine roots; few coarse to fine stones; 2-5% fine gravel; slightly acid; gradual smooth boundary.
A3	36 – 51 cm; black (2.5Y 2/1) loam; few fine distinct very dark grayish brown (10YR 3/2) Fe mottles; moderate fine subangular blocky structure; friable; few fine roots; 2% fine gravel; neutral; clear smooth boundary.
AB	51 – 64 cm; very dark gray (2.5Y 3/1) loam; few fine distinct very dark grayish brown (10YR 3/2) mottles; moderate fine subangular blocky structure; friable; common fine and very fine roots; few fine round stones; 1-2% fine gravel; neutral; clear smooth boundary.
Bg1	64 – 79 cm; very dark gray (10YR 3/1) loam; common fine to medium faint very dark grayish brown (10YR 3/2) mottles; moderate fine subangular blocky structure; friable; common fine roots; few fine round stones; 1-2% fine gravel; neutral; clear smooth boundary.
Bg2	79 – 91 cm; dark grayish brown (2.5Y 4/2) and very dark gray (2.5Y 3/1) loam; few fine prominent dark yellowish brown (10YR 4/6) mottles; few fine distinct olive brown (2.5Y 4/4) mottles; moderate fine subangular blocky structure; friable; common fine roots; few fine stones; 1-2% fine gravel; slightly alkaline; abrupt smooth boundary.
Bg3	91 – 99 cm; varied dark grayish brown (2.5Y 4/2), olive brown (2.5Y 4/4) and very dark gray (2.5Y 3/1) loam; few fine prominent dark yellowish brown (10YR 4/8) mottles; weak fine subangular blocky structure; friable; few fine roots; few fine stones; 1-2% fine gravel; slightly alkaline; abrupt smooth boundary.
2Ckg	99 – 107 cm; light olive brown (2.5Y 5/4) and light brownish gray (2.5Y 6/2) silt loam; few medium very dark gray (2.5Y 3/1) organic coatings on ped faces; few fine distinct dark yellowish brown (10YR 4/4) mottles; moderate medium subangular blocky structure; slightly firm; few fine $CaCO_3$ concretions and streaks; few fine stones; moderate reaction to 10% HCl; moderately alkaline; clear smooth boundary.
3Ckg1	107 – 119 cm; light brownish gray (2.5Y 6/2) silt loam; many fine distinct olive brown (2.5Y 4/4) mottles; few medium prominent light olive brown (2.5Y 5/6) mottles; few fine very dark gray (2.5Y 3/1) organic coatings on ped faces; massive; firm; many fine $CaCO_3$ concretions and streaks; few fine roots; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.

Horizon	Soil Description
3Ckg2	119 – 135 cm; light brownish gray (2.5Y 6/2) silt; common medium to fine prominent light olive brown (2.5Y 5/6) mottles; few medium prominent dark yellowish brown (10YR 4/6) mottles; massive; slightly firm; very few fine roots; few Mn concretions; common $CaCO_3$ streak; strong reaction to 10% HCl; strongly alkaline; clear smooth boundary.
3Ckg3	135 – 168 cm; light brownish gray (2.5Y 6/2) silt; few medium and fine prominent dark yellowish brown (10YR 4/6) mottles; few fine prominent light olive brown (2.5Y 5/6) mottles; massive; firm; very few fine roots; common $CaCO_3$ streaks; strong reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
4Cg	168 – 183 cm; grayish brown (2.5Y 5/2) and olive brown (2.5Y 4/4) sandy loam; few medium prominent light olive brown (2.5Y 5/6) mottles; massive; firm; common to fine stones; strong reaction to 10%HCl; strongly alkaline; clear smooth boundary.
5Cg1	183 – 193 cm; light brownish gray (2.5Y 6/2) and grayish brown (2.5Y 5/2) loam; few fine prominent light olive brown (2.5Y 5/6) mottles; massive; friable; strong reaction to 10% HCl; strongly alkaline; abrupt smooth boundary.
6Cg2	193 – 203 cm; varied light brownish gray (2.5Y 6/2), grayish brown (2.5Y 5/2), and olive brown (2.5Y 4/4) loam; few fine prominent to distinct dark yellowish brown (10YR 4/6) mottles; massive; friable; many coarse to fine stones; strong reaction to 10% HCl; strongly alkaline; abrupt smooth boundary.
7Cg	203 – 213 cm; varied light brownish gray (2.5Y 6/2), grayish brown (2.5Y 5/2), olive brown (2.5Y 4/4), and dark yellowish brown (10YR 4/6) sandy loam; loose; friable; strong reaction to 10% HCl; strongly alkaline; many coarse to fine stones.

Characterization data for well 3 on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dol. %	Ratio
A1	0 – 20	38.8	19.8	16.4	25.0	2.65	-	-	4.56	6.1	-	-	-
A2	20 – 36	35.2	18.3	19.4	27.0	2.21	-	-	3.80	6.4	-	-	-
A3	36 – 51	38.0	17.1	18.8	26.1	1.75	-	-	3.01	6.7	-	-	-
AB	51 – 64	39.5	16.4	19.3	24.7	1.20	-	-	2.06	6.9	-	-	-
Bg1	64 – 79	41.6	15.8	19.1	23.6	0.97	2.9	0.35	1.07	7.2	1.0	1.8	0.56
Bg2	79 – 91	38.1	17.0	20.8	24.2	0.76	2.9	0.35	0.46	7.5	0.7	2.0	0.35
Bg3	91 – 99	39.7	17.4	22.7	20.1	1.24	13.8	1.65	-	7.8	1.2	11.6	0.10
2Ckg	99 – 107	26.8	21.2	34.0	17.9	2.42	17.5	2.10	-	8.1	6.1	10.5	0.58
3Ckg1	107 – 119	9.4	21.3	53.0	16.3	-	27.7	3.33	-	8.4	13.8	12.8	1.08
3Ckg2	119 – 135	5.5	28.6	56.1	9.7	-	24.3	2.92	-	8.5	6.8	16.1	0.42
3Ckg3	135 – 168	6.2	30.0	50.9	12.9	-	23.3	2.80	-	8.4	6.1	15.8	0.39
4Cg	168 – 183	58.2	14.8	16.1	10.9	-	18.0	2.15	-	8.6	4.7	12.2	0.39
5Cg1	183 – 193	47.1	24.1	18.2	10.7	-	17.5	2.10	-	8.6	4.5	12.0	0.38
6Cg2	193 – 203	50.9	20.5	18.6	10.0	-	19.0	2.28	-	8.6	4.0	13.8	0.29
7Cg	203 – 218	75.4	9.4	8.3	6.9	-	20.5	2.46	-	8.6	6.0	13.3	0.45

GPS Coordinates:

42.23.6509N 93.52.6748W

Soil descriptions for well 4 on transect 3.

Canisteo loam Bromegrass prairie Footslope Position
Fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll

Horizon	Soil Description
A1	0 – 15 cm; black (N 2/0) loam; moderate fine subangular blocky structure; friable; common coarse and medium roots; many very fine and fine roots; 2-5% fine gravel; neutral; gradual smooth boundary.
A2	15 – 33 cm; black (N 2/0) loam; very few fine prominent dark grayish brown (2.5Y 4/2) mottles; moderate fine subangular blocky structure; friable; common fine and many very fine roots; 2-5% fine gravel; few stones; slightly alkaline; clear smooth boundary.
2A	33 – 53 cm; black (N 2/0) loam; few fine prominent dark grayish brown (2.5Y 4/2) mottles; moderate fine subangular blocky structure; friable; grayish brown (2.5Y 5/2) clay films on ped faces; few fine roots; few stones; slightly alkaline; slight reaction to 10% HCl; clear smooth boundary.
2Bg1	53 – 69 cm; very dark gray (2.5Y 3/1) sandy loam; common very fine faint (2.5Y 4/2) mottles; few fine distinct olive brown (2.5Y 4/4) mottles; moderate fine subangular blocky structure; friable; few fine roots; few stones; shell fragments; slight reaction to 10% HCl; moderately alkaline; abrupt smooth boundary.
2Bg2	69 – 89 cm; very dark gray (2.5Y 3/1) and gray (5Y 5/1) loam; few fine distinct olive brown (2.5Y 4/4) mottles; moderate medium subangular blocky structure; slightly firm; few fine and common very fine roots; strong reaction to 10% HCl; few coarse to fine stones; few shell fragments; moderately alkaline; abrupt smooth boundary.
2Cg1	89 – 107 cm; gray (5Y 5/1) loam; few very dark gray (2.5Y 3/1) organic masses on ped faces; common fine prominent olive brown (2.5Y 4/4) mottles; few fine prominent; light olive brown (2.5Y 5/6) mottles; moderate fine prismatic structure; friable; few fine and very fine roots; strong reaction to 10% HCl; common fine and medium stones; moderately alkaline; clear smooth boundary.
2Cg2	107 – 122 cm; gray (5Y 5/1) loam; common fine to medium prominent olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR 4/6) mottles; massive; slightly firm; few fine roots; sand lenses between ped faces; few medium to fine roots; strong reaction to 10% HCl; moderately alkaline; gradual smooth boundary.
3Cg	122 – 157 cm; gray (5Y 5/1) loam; common fine to medium prominent olive brown (2.5Y 4/4) mottles; massive; firm; few fine stones; very few roots; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
4Cg1	157 – 193 cm; dark gray (5Y 5/1) loam; few medium prominent olive brown (2.5Y 4/4) mottles; few medium and coarse prominent dark yellowish brown (10YR ¾) mottles; massive; firm; very few roots; common fine stones; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.

Horizon	Soil Description
4Cg2	193 – 229 cm; dark gray (5Y 5/1) loam; many fine to medium prominent olive brown (2.5Y 4/4) mottles; few fine prominent dark yellowish brown (10YR ¾) mottles; massive; firm; common coarse to fine stones; moderately alkaline; strong reaction to 10% HCl.

Characterization data for well 4 on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolomite %	Ratio
A1	0 – 15	33.0	22.5	20.3	24.3	4.23	3.4	0.40	6.59	7.1	0.7	2.5	0.28
A2	15 – 33	33.7	21.8	20.3	24.2	3.03	4.9	0.59	4.20	7.4	1.1	3.5	0.31
2A	33 – 53	52.5	17.3	14.2	16.0	1.34	6.3	0.76	1.00	7.7	0.4	5.5	0.07
2Bg1	53 – 69	54.0	16.1	14.4	15.4	1.68	13.0	1.56	0.21	7.9	3.5	8.7	0.40
2Bg2	69 – 89	48.2	16.7	17.7	17.3	1.95	14.6	1.75	0.34	7.9	3.9	9.8	0.40
2Cg1	89 – 107	45.5	15.9	17.7	20.9	-	21.0	2.52	-	8.0	6.6	13.3	0.50
2Cg2	107 – 122	39.4	15.7	21.7	23.3	-	22.0	2.64	-	8.0	5.7	15.0	0.38
3Cg	122 – 157	28.9	15.0	31.8	24.2	-	21.0	2.52	-	7.9	5.5	14.3	0.38
4Cg1	157 – 193	40.2	15.7	21.9	22.2	-	18.7	2.25	-	7.9	6.5	11.2	0.58
4Cg2	193 – 229	40.5	15.6	21.6	22.3	-	21.9	2.63	-	8.0	5.9	14.7	0.40

GPS Coordinates:

42.23.6294N 93.52.6787W

Soil descriptions for well 5 on transect 3

Klosssner muck   Reed Canary Grass Wetland Zone   Footslope Position
Fine-loamy, mixed, euic, mesic Terric Haplosaprist

Horizon	Soil Description
Oi	0 – 10 cm; fibrous; many coarse, medium, fine to very fine roots; abrupt smooth boundary.
A1	10 – 38 cm; black (2.5Y 2/0) silty clay loam; weak fine granular structure; friable; many very fine to fine roots; neutral; gradual smooth boundary.
A2	38 – 71 cm; black (2.5Y 2/0) silty clay loam; weak fine subangular blocky structure; friable; many fine to very fine roots; neutral; clear smooth boundary.
2A1	71 – 99 cm; black (2.5Y 2/0) loam; few fine distinct dark grayish brown (2.5Y 4/2) mottles; moderate fine subangular blocky structure; friable; 2% fine gravel; common fine roots; slightly alkaline; clear smooth boundary.
2A2	99 – 119 cm; black (2.5Y 2/0) loam; common medium to fine distinct dark grayish brown (2.5Y 4/2) mottles; moderate fine subangular blocky structure; friable; 2% fine gravel; few fine stones; few fine roots; moderately alkaline; slight reaction to 10% HCl; abrupt smooth boundary.
3Cg	119 – 157 cm; varied black (2.5Y 2/0), gray (5Y 5/1), and dark gray (5Y 4/1) silt loam; few medium prominent olive brown (2.5Y 4/4) mottles and pore linings; massive; firm; few fine roots; strong reaction to 10% HCl; moderately alkaline; clear smooth boundary.
4Cg1	157 – 180 cm; varied olive brown (2.5Y 4/4) and dark gray (5Y 4/1) loam; common fine prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few fine to medium roots in the 5 cm; few fine to medium stones; moderately alkaline; strong reaction to 10% HCl; abrupt smooth boundary.
4Cg2	180 – 221 cm; varied dark gray (5Y 4/1) and dark grayish brown (2.5Y 4/2) loam; common fine prominent dark brown (7.5YR ¾) mottles and concretions; few fine prominent dark yellowish brown (10YR 4/6) mottles; massive; firm; few fine to medium stones; strong reaction to 10% HCl; moderately alkaline.

Characterization data for well 5 on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dol. %	Ratio
Oi	0 – 10	-	-	-	-	-	-	-	-	-	-	-	-
A1	10 – 38	12.9	25.1	30.7	31.3	7.10	-	-	18.0	6.9	-	-	-
A2	38 – 71	21.6	21.7	29.0	27.6	4.64	3.1	0.38	7.3	7.0	0.7	2.2	0.32
2A1	71 – 99	38.2	18.2	19.9	23.8	3.38	2.9	0.35	5.2	7.4	1.0	1.8	0.56
2A2	99 – 119	43.8	19.2	17.9	19.1	1.73	7.0	0.84	1.5	7.9	0.3	6.1	0.05
3Cg	119 – 157	11.7	22.9	39.3	26.1	1.83	9.2	1.10	1.3	8.0	1.8	6.7	0.27
4Cg1	157 – 180	39.8	23.8	22.1	14.3	-	18.8	2.26	-	8.2	4.2	13.5	0.31
4Cg2	180 – 221	35.6	16.8	27.3	20.3	-	20.3	2.43	-	8.1	5.7	13.4	0.43

GPS Coordinates:

42.23.6152N 93.52.6787W

Soil descriptions for well 6 on transect 3

Klossner muck Reed Canary Grass Wetland Zone Toeslope Position
Fine, smectitc, euic, mesic Terric Haplosaprist

Horizon	Soil Description
Oi	0 – 8 cm; Fibrous; many fine roots; 80-90% fibers; neutral; abrupt smooth boundary.
Oa	8 – 25 cm; black (N 2/0) silt loam; weak fine granular structure; friable; common fine and many very fine roots; slightly acid; abrupt smooth boundary.
A	25 – 46 cm; black (5Y 2/1) silty clay loam; weak fine subangular blocky structure; friable; common fine and many very fine roots; slightly acid; abrupt smooth boundary.
Cg	46 – 51 cm; light gray (5Y 7/2) and dark gray (5Y 4/1) silty clay loam; common prominent dark yellowish brown (10YR ¾) pore linings; weak fine subangular blocky structure; friable; common fine roots; neutral; abrupt smooth boundary.
2A1	51 – 81 cm; black (2.5Y 2/1) silty clay loam; few prominent dark yellowish brown (10YR ¾) pore linings; weak fine subangular blocky structure; friable; common fine to very fine roots; neutral; clear smooth boundary.
2A2	81 – 102 cm; black (2.5Y 2/0) silty clay loam; few prominent dark yellowish brown (10YR ¾) pore linings and mottles; massive; friable; few fine roots; neutral; clear smooth boundary.
2A3	102 – 142 cm; black (2.5Y 2/0) silty clay loam; few medium distinct dark grayish brown (2.5Y 4/2) mottles; few fine prominent dark yellowish brown (10YR ¾) pore linings and mottles; massive; slightly firm; slightly alkaline; clear smooth boundary.
2A4	142 – 191 cm; black (2.5Y 2/0 and 5Y 2/1) silty clay loam; few fine prominent dark yellowish brown (10YR ¾) pore linings; few medium distinct dark grayish brown (2.5Y 4/2) mottles; massive; slightly firm; slightly alkaline; abrupt smooth boundary.
2Cg	191 – 198 cm; light brownish gray (2.5Y 6/2) and dark gray (5Y 4/1) silt loam; few black (2.5Y 2/0) organic masses on ped faces; weak fine subangular blocky structure; friable; slightly alkaline; abrupt smooth boundary.
3Oa	198 – 206 cm; black (2.5Y 2/0) loam; weak fine granular structure; friable; strongly acid.

Characterization data for well 6 on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
Oi	0 – 8	-	-	-	-	26.63	-	-	45.8	6.6	-	-	-
Oa	8 – 25	9.4	48.0	24.0	18.7	20.09	-	-	34.6	6.5	-	-	-
A	25 – 46	5.6	17.0	40.6	36.8	7.45	-	-	12.8	6.5	-	-	-
Cg	46 – 51	6.4	22.7	38.9	32.0	2.80	-	-	4.8	6.8	-	-	-
2A1	51 – 81	2.8	27.9	33.5	35.9	8.58	-	-	14.8	6.8	-	-	-
2A2	81 – 102	1.8	25.1	34.9	38.2	4.56	2.7	0.32	7.3	7.0	0.5	2.0	0.25
2A3	102 – 142	2.6	22.9	37.2	37.3	3.74	7.6	0.91	4.9	7.5	1.4	5.6	0.25
2A4	142 – 191	1.7	22.9	37.3	38.1	3.60	4.2	0.51	5.3	7.5	0.9	3.1	0.29
2Cg	191 – 198	6.6	24.3	50.3	18.8	5.14	4.0	0.48	8.0	7.5	1.1	2.6	0.42
3Oa	198 +	33.4	18.5	30.6	17.5	26.09	-	-	44.9	3.7	-	-	-

GPS Coordinates:

42.23.5918N 93.52.6826W

Soil descriptions for well 7 on transect 3

Klossner muck Reed Canary Grass Wetland Zone Toeslope Position
Fine, smectitic, euic, mesic Terric Haplosaprist

Horizon	Soil Description
Oi	0 – 5 cm; fibrous; 80-90% fibers; many fine to very fine roots; slightly acid; abrupt smooth boundary.
A1	5 – 28 cm; black (N 2/0) silty clay loam; weak fine subangular blocky structure; friable; many fine to very fine roots; neutral; abrupt smooth boundary.
A2	28 – 43 cm; black (N 2/0 and 5Y 2/1) silty clay loam; moderate fine subangular blocky structure; friable; common fine to many very fine roots; neutral; clear smooth boundary.
A3	43 – 61 cm black (N 2/0) silty clay loam; few fine prominent very dark grayish brown (2.5Y 3/2) pore linings; moderate fine subangular blocky structure; friable; common fine and many very fine roots; neutral; clear smooth boundary.
A4	61 – 79 cm; black (2.5Y 2/0) silty clay loam; moderate medium subangular blocky structure; friable; common fine and very fine roots; neutral; clear smooth boundary.
A5	79 – 102 cm; black (2.5Y 2/0) silty clay loam; massive; friable; very few and very fine roots; neutral; abrupt smooth boundary.
A6	102 – 109 cm; light olive brown (2.5Y 5/4) and black (2.5Y 2/0) silty clay loam; massive; friable; slightly alkaline; abrupt smooth boundary.
A7	109 – 142 cm; black (2.5Y 2/0) silty clay; few fine prominent dark yellowish brown (10YR ¾) mottles and pore linings; very few fine distinct very dark grayish brown (2.5Y 3/2) mottles; massive; slightly firm; slightly alkaline; clear smooth boundary.
A8	142 – 188 cm; black (2.5Y 2/0 and 5Y 2/1) and silty clay loam; few medium distinct very dark grayish brown (2.5Y 3/2) mottles; very few fine dark yellowish brown (10YR ¾) mottles and pore linings; massive; friable; slightly alkaline; clear smooth boundary.
2Oa	188 + cm; black (2.5Y 2/0) silt loam; weak fine subangular blocky structure; friable; strongly acid.

Characterization data for well 7 on transect 3 in Gordon's Marsh.

Horizon	Depth cm	Sand %	Coarse Silt %	Fine Silt %	Clay %	TC %	CCE %	IC %	OM %	pH	Calcite %	Dolo. %	Ratio
Oi	0 – 5	-	-	-	-	32.99	-	-	54.2	6.5	-	-	-
A1	5 – 28	4.9	23.9	38.5	32.7	7.51	-	-	12.9	6.6	-	-	-
A2	28 – 43	4.5	17.6	40.1	37.8	5.57	-	-	9.6	6.7	-	-	-
A3	43 – 61	2.9	21.2	39.4	36.6	5.91	-	-	10.2	6.9	-	-	-
A4	61 – 79	2.7	21.5	36.7	39.1	5.01	4.0	0.48	7.8	7.1	1.1	2.7	0.41
A5	79 – 102	2.4	18.4	39.5	39.7	3.68	2.2	0.27	5.9	7.3	0.5	1.6	0.31
A6	102 – 109	4.9	19.2	42.0	33.8	3.41	3.3	0.40	5.2	7.4	0.9	2.2	0.41
A7	109 – 142	1.8	20.2	36.8	41.2	3.44	4.5	0.53	5.0	7.6	0.7	3.5	0.20
A8	142 – 188	2.9	17.4	43.8	36.0	3.23	14.0	1.68	2.7	7.7	2.1	11.0	0.19
20a	188 +	15.1	25.3	39.0	20.6	13.04	-	-	21.7	3.7	-	-	-

GPS Coordinates:

42.23.5649N 93.52.6885W